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## ZOOLOGICAL SCIENCES

### Contents

	Page
The Biology of <i>Cephalonomia waterstoni</i> Gahan— <i>R. Omar Rilett</i> - - - - -	93
The Biology of <i>Laemophloeus ferrugineus</i> (Steph.)— <i>R. Omar Rilett</i> - - - - -	112
Studies of Waterfowl in British Columbia. Green-winged Teal — <i>J. A. Munro</i> - - - - -	149

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# Canadian Journal of Research

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NUMBER 3

## THE BIOLOGY OF *CEPHALONOMIA WATERSTONI* GAHAN<sup>1</sup>

BY R. OMAR RILETT<sup>2</sup>

### Abstract

Life history and morphological studies were made on *Cephalonomia waterstoni* Gahan, a hymenopterous parasite on the larval and pupal stages of the rusty grain beetle, *Laemophloeus ferrugineus* (Steph.). At 90° F. and 65 to 75% relative humidity the whole life cycle of *C. waterstoni* is completed within 12 to 13 days. The adult life span of females is about three weeks, while that of males is much shorter. The male, which prior to this work was unknown, can easily be distinguished from the female by its smaller size, its less rectangular-shaped head, and its longer antennae. The first flagellar segments of the males are brownish-black in color while those of the females are yellowish. The ratio of females to males is somewhere near 2 : 1. The ease with which the parasite *C. waterstoni* can be reared in large numbers in the laboratory, and its remarkable ability to check infestations of *L. ferrugineus* under experimental conditions, indicate that this species might be of value in biological control programs for *L. ferrugineus* in warehouses, mills, and elevators.

### Introduction

*Cephalonomia waterstoni* Gahan, a minute parasitic wasp belonging to the family Bethylidae, was first described by Gahan in 1931 (1). The description of the species was made from 11 female specimens taken at quarantine in Washington, D.C. by E. A. Back from a shipment of grain the original source of which was said to be Australia; from four females collected from stored corn at Baton Rouge, La., by C. O. Hopkins; and from one female taken at Urbana, Ill., by W. V. Balduf.

Gahan (1) examined numerous female specimens of this species now in the British Museum and these are the same insects as those listed in the Royal Society's 9th Report of the Grain Pests (War) Committee, 1921, listed under the name *Cephalonomia* sp. (p. 50) and comprising the lots numbered 247, 262, 266, 347, 348, 349, 370, 384, 386, 389, and 390 of that report.

In 1931 the species had not yet been associated with any definite host, but it was thought that it was probably parasitic upon one or more of the Coleoptera that infest stored grain.

<sup>1</sup> Manuscript received February 4, 1949.

The research reported in this paper was conducted in the Zoological Laboratory of the University of Wisconsin and was supported in part by the Wisconsin Alumni Research Foundation.

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Since 1931 it has been established that *Cephalonomia waterstoni* is a parasite on the larvae of *Laemophloeus minutus* Ol. (*pusillus* Schonh.) (2) and on the larvae of *Laemophloeus ferrugineus* (Steph.) (4).

This parasite has been taken in considerable numbers by the writer in grain from a flour mill at London, Ont., and in grain from the University of Wisconsin feed storage building. The wasp appeared in the cultures of *Laemophloeus ferrugineus* being kept in the Zoological Laboratory at Madison during the summer of 1944, shortly after the original culture had arrived from Canada. Thus it is not known whether the parasite became established in the beetle cultures after reaching Madison or before leaving Canada.

Mr. C. F. W. Muesebeck, Washington, D.C., who identified specimens from cultures used in this investigation, informed the writer by letter that practically nothing was known concerning the biology of *Cephalonomia waterstoni*. It was therefore decided to supplement the study of *Laemophloeus ferrugineus*, which was then under way, with a study of the biology of its parasite, *Cephalonomia waterstoni*, paying special attention to the possibilities of using the latter as an agent in the biological control of the former.

#### Life History of *Cephalonomia waterstoni* Gahan at 90° F. and 65 to 75% Relative Humidity

*Cephalonomia waterstoni* females lay their eggs on the larvae and in some instances the pupae of *Laemophloeus ferrugineus* (Steph.). The fourth instar larva is the stage usually parasitized, no eggs having been found on the first or second instars, although the female parasite attacks the younger larvae just as ferociously as she does the older ones. Usually one or two (rarely three) eggs are deposited on a single host larva. Of 408 parasitized larvae examined, 210 had one egg, 190 had two eggs, and eight had three eggs adhering to them.

The eggs are almost always deposited just caudad to the host's metathoracic legs on the ventral lateral margin of the first two or three abdominal segments (Fig. 1). However, eggs may be found anywhere on the ventral, lateral, or dorsal sides of the abdomen or thorax of the host.

The gravid female wasp searches for a suitable larva upon which to oviposit and, when she finds one, attacks it immediately. Once her powerful mandibles have closed upon her prey its escape is impossible. Although the larva is much larger than its attacker, all of its twisting and lashing movements, which throw the attacking female violently to and fro, are to no avail, and it finally is stung into submission. The struggle may last for several minutes, during which the parasite may make several attempts to pierce the larva's integument with her slim, lancelike ovipositor, which functions primarily as a poison-injecting instrument (Figs. 26 and 27), before she is successful in stinging her victim. The stung larvae, apparently paralyzed, is carried off by its conqueror to a secluded spot where oviposition takes place. In the rearing cages, where there was no place in which to hide, the female wasp

would restlessly carry the paralyzed larva around the cage, and often she would continue this fruitless activity after she had deposited eggs upon it. Infrequently the paralyzing effect of the sting was not permanent and the parasitized larva, with the eggs adhering to it, would become active and crawl about in the cage.

The stinging apparatus does not function as an ovipositor, although it has a function at the time of oviposition. When the egg is being laid the first and second valvulae of the stinging apparatus are extended posteriorly and the egg emerges from the female genital duct ventral to the valvulae. The valvulae are used to press the egg tightly against the larva, and after the egg is laid they are run back and forth over it to make sure that it is closely appressed to the body of the host. In a short time the egg becomes rather firmly stuck to the exoskeleton of the host larva. It takes a little over a minute for the egg to be laid, and it is forced to the outside by a "shunting" motion of the posterior abdominal segments. The female maintains her oviposition posture upon the larval host for a few minutes after the egg is laid.

The white and almost transparent eggs "hatch" about 30 hr. after they are laid and the parasite larvae reach their full size about 23 hr. later. Thus it is only a little over two days from the time the eggs are laid until the resulting larvae are full grown. Approximately two hundred different individuals were observed daily as they developed from egg to adult. Records of these daily examinations were kept, but the variations in the length of the developmental periods for the different individuals were so small that the detailed data are omitted here. Almost without exception the insect completed its development from egg to adult in 11 or 12 days.

The parasite larva (Figs. 2 and 23) keeps the same position on the host as that occupied by the egg, and since the egg gradually increases in size up to the time of hatching it is very difficult to determine the exact time that the chorion is shed. This difficulty is increased because of the extreme thinness of the chorion, which remains undetectable under a binocular dissecting microscope. The time given above for the hatching of the larva was recorded at the stage of development at which a slight knoblike protuberance appeared at one end of the "egg". This was interpreted as the appearance of the anterior end of the larva from the egg, but whether the chorion actually surrounded the rest of the larva at this time was not determined.

The parasite larva grows very rapidly and reaches its full growth in one day (Fig. 23). It feeds by inserting its anterior end into the host and sucking up the fluid contents of the haemocoel. The host larva must remain alive until the parasite has reached its full larval size or the latter will fail to develop. *Cephalonomia waterstoni* larvae develop so rapidly that when two eggs are laid on the same host, the one that hatches last will usually be smaller than the other (Fig. 23). A full-grown *Laemophloeus ferrugineus* larva provides just about enough food for the complete development of two parasite larvae. In those instances in which three eggs were deposited on a single host larva the first parasite larva to start feeding was usually the only one to complete

its development. However, in one case three adult parasites developed upon one host larva. In this instance the parasite larvae all started feeding at approximately the same time and as a result all received the same proportion of food. None of these larvae reached full size and the resulting adults were much smaller than normal.

The number of larval stadia was not determined. Fritz Van Emden (5), working with *Cephalonomia quadridentata* Duchaussoy, reported five stadia for the above species. He determined the different larval instars by measuring the spiracular diameters of the shed exuviae, which accumulated on the ventral side of the fifth instar between it and the host. He found four sets of spiracles of different sizes and concluded that each set represented a different instar. No such study was made on *Cephalonomia waterstoni* but probably the number of stadia would be the same as for *Cephalonomia quadridentata*.

When the *Cephalonomia waterstoni* larvae have reached their full size they leave the host, which has by then been reduced to an empty shell with nothing remaining but the head and collapsed body wall, and spin oval-shaped, white, silken cocoons (Fig. 4). Soon after the completion of the cocoon the larva changes into the prepupal stage (Fig. 5) and a little later it gives off a mass of black fecal material that forms a dark globule at one end on the cocoon. Apparently the contents of the intestine are voided just before pupation. The period from the start of the spinning of the cocoon until the prepupal stage is reached is about two days. The prepupal stage lasts another two days, when ecdysis occurs and the pupal stage appears (Figs. 5 and 6). The pupal stage in turn lasts for five days, when the last molt occurs and the imago emerges. Shortly afterward it chews a circular opening through the cocoon and escapes to the outside.

If males are present the females are mated shortly after they emerge. There is no preliminary courtship behavior. The male, upon encountering a female that is physiologically ready to mate, mounts her abdomen to which he holds with all three pairs of legs. Then bending his abdomen downward and forward he inserts the aedeagus into the female genital opening. Fig. 24 shows the male genital clasping organs, which aid in the copulatory act. Copulation lasts for about a minute to one and one-half minutes. Mated females may give rise to both female and male progeny but unmated females have only male offspring. Adult females when only one day old may start laying eggs. Therefore at 90° F. and 65 to 75% relative humidity the whole life cycle of *Cephalonomia waterstoni* is completed within 12 to 13 days. The adult life span of females is about three weeks, while that of males is much shorter. Virgin females may live long enough to mate with their own offspring. This fact was brought out when a young male was observed in copulation with his previously unmated mother. Therefore it would be possible for a single unmated female to set up parasitic infestation among host larvae by mating with one of her first male offspring, after which time she would be able to produce female as well as male progeny.

Adult *Cephalonomia waterstoni* females apparently feed upon the larvae of *Laemophloeus ferrugineus* for they have frequently been observed chewing captured host larvae. It seems probable that this wasp chews a hole through the cuticula of its prey and drinks the fluid that oozes out through the opening.

#### Description of Stages in the Life Cycle of *Cephalonomia waterstoni* Gahan

##### *The Egg (Fig. 1)*

The white shiny eggs vary from 0.192 mm. to 0.356 mm. in length and from 0.069 mm. to 0.163 mm. in width. This wide variation in the size of different eggs is partly due to the increase in size of the egg after it is laid. The eggs are slightly curved with both ends bluntly rounded. The chorion and vitelline membrane are very thin and structureless, and so transparent that pulsations of the embryo are plainly visible within the egg. The embryo likewise is colorless and transparent, and the pulsations just mentioned appear as rhythmic waves of a slightly opaque fluid moving at regular intervals from one end of the egg to the other.

##### *The Larva (Figs. 2, 3, and 23)*

The yellowish-white, somewhat pear-shaped larvae are completely legless, and are not distinctly divided into head, thoracic, and abdominal regions. The head end is narrower than the abdomen, which is bluntly rounded to a point at the anal end. Behind the head three thoracic segments and nine abdominal segments are visible. The segmentation is very indistinct, as shown in Fig. 2. The mouth parts of the head are not sufficiently sclerotized to make them visible even when the larva is stained and mounted on a slide. It is assumed therefore that the mouth parts are very rudimentary, and that the structures that are present are mostly membranous. A protrusion, which probably corresponds to the labium, is visible on the ventral side of the anterior end of the larva.

The abdomen when viewed with reflected light has several white, approximately circular clusters that apparently lie in or just under the cuticula of the abdomen. They appear dark in color when viewed by transmitted light.

The full-grown larvae are from 1.5 to 2.0 mm. in length, although the attainment of normal growth is dependent upon the amount of food available.

In the prepupal stage the shape of the pupa begins to take form; the division of the larva into three body regions, head, thorax, and abdomen, becoming more distinct (Fig. 5).

##### *The Pupa (Figs. 5 and 6)*

The pupa, which at first is creamy white in color with a slight greenish tinge to the abdomen, shows the characteristic structures of the adult. The head is bent ventrad and caudad under the prothorax, and the antennae are directed

posteriorly and medially, so that their tips almost meet on the ventral side of the anterior segments of the abdomen. The legs lie along the ventral lateral edges of the thorax and extend caudad ventrally along the sides of the abdomen. The anlagen of the two pairs of wings extend ventrally over the second pair of legs in a diagonal direction towards the median and posterior part of the body.

The large compound eyes and ocelli begin to show a light brown pigmentation by the end of the first day of pupation, and by the second day they are quite dark in color. On the third day the abdomen begins to turn black and a "wave" of pigmentation spreads cephalad. By the fourth day the entire pupa is jet black, with the exception of the legs and antennae (Fig. 6). On the fifth day the shiny black adult emerges.

#### *The Adult*

The female was described by Gahan as a new species in 1931. Prior to the present work the male was unknown.

The description of the species as given by Gahan follows:

"Female.—Length 1.6 mm. Black and shining; mandibles, pedicel, and first flagellar joint more or less, and all tarsi yellowish; antennal flagellum and the tibiae brownish black; wings hyaline or with a very faint discal cloud. Head viewed from in front longer than broad (20 : 16), the sides nearly parallel or very slightly convex; eyes situated much nearer to mouth than to vertex, about their own length below vertex; ocelli distinct, in an equilateral triangle; whole head finely reticulate-punctate. Antennae inserted at clypeus, 12-jointed; scape two and one-half to three times as long as broad, pedicel about one and one-half times as long as broad, joints 3 to 11 subquadrate, joint 12 about twice as long as broad. Thorax flattened dorsally and with reticulate-punctate sculpture like the head; pronotum about three times the length of mesoscutum, much narrower anteriorly than posteriorly; mesoscutum without longitudinal grooves; scutellum distinctly longer than mesoscutum, with a short groove or pit on either side of base; propodeum flat, in the same plane as scutellum, as long as pronotum, distinctly narrower at apex than at base, sculptured like the thorax, finely margined laterally and at apex of dorsum, a very delicate median longitudinal carina present or absent, the lateral and posterior faces sculptured like the dorsum. Wings well-developed, the prostigma and pterostigma very small, other veins except the submarginal effaced, the forewing without basal cells. Legs normal, the femora moderately swollen, the hind tarsi longer than their tibia. Abdomen ovate, a little broader than the thorax and subequal to it in length, smooth and polished, the third tergite with a barely perceptible suggestion of a depression on each side of the middle.

Male.—Unknown.

Type locality.—Australia.

Type.—Cat. No. 43361, U.S.N.M."

PLATE I

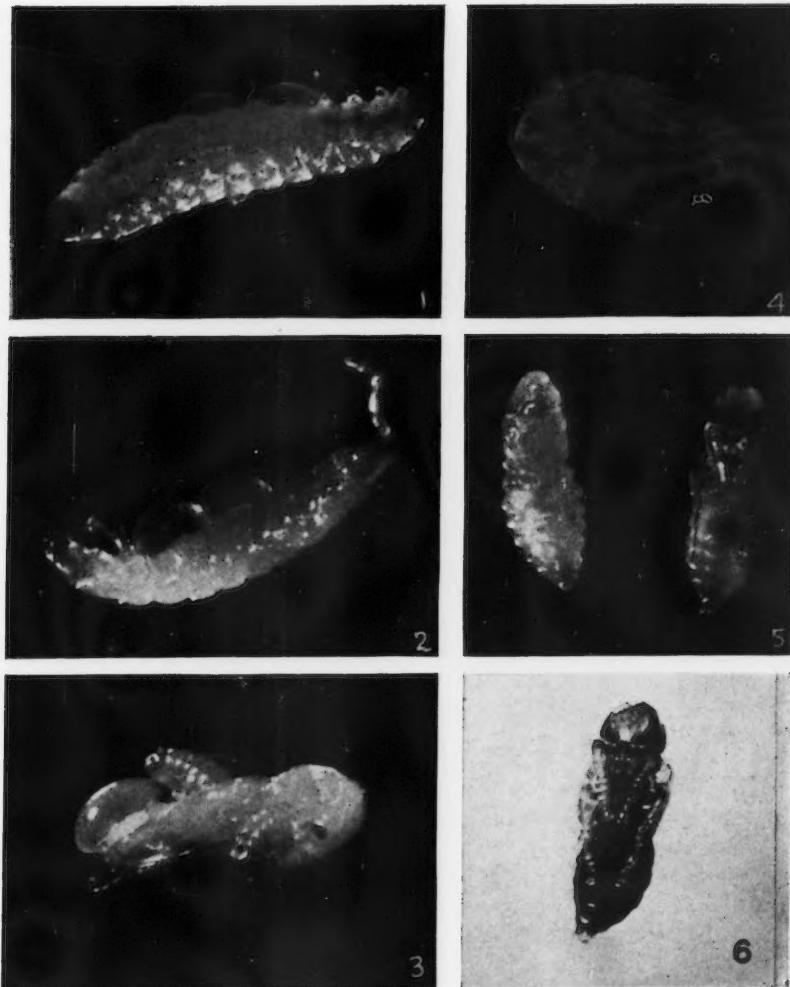


FIG. 1. Eggs of *Cephalonomia waterstoni* on a larva of *Laemophloeus ferrugineus*.

FIG. 2. Young larvae of *Cephalonomia waterstoni* feeding on a larva of *Laemophloeus ferrugineus*.

FIG. 3. Young larvae of *Cephalonomia waterstoni* feeding on a pupa of *Laemophloeus ferrugineus*.

FIG. 4. Cocoon of *Cephalonomia waterstoni*.

FIG. 5. Prepupa and early pupa stage of *Cephalonomia waterstoni*.

FIG. 6. Late pupa stage of *Cephalonomia waterstoni*.



The male can be easily distinguished from the female by its smaller size, its less rectangular-shaped head and its longer antennae. Males have the first flagellar joints brownish-black in color, instead of yellowish as in the case of the female. The male is about three-fourths as long as the female. Table I lists the lengths of 12 males and 12 females. It should be recalled that many

TABLE I  
LENGTH MEASUREMENTS OF 24 *Cephalonomia waterstoni* ADULTS

Males		Females	
Insect number	Length in mm.	Insect number	Length in mm.
1	1.6	1	1.9
2	1.5	2	2.0
3	1.5	3	1.9
4	1.6	4	2.1
5	1.6	5	1.9
6	1.1	6	1.9
7	1.2	7	2.0
8	1.5	8	2.0
9	1.2	9	1.7
10	1.2	10	2.0
11	1.5	11	1.9
12	1.6	12	2.0
Average	1.4	Average	1.9

adults may be much smaller than normal because of retarded larval development due to a paucity of food. None of these small individuals were included in the measurements listed. The adult is greatly flattened dorsoventrally and the wings when at rest are held so that one pair fits over the other pair along the back of the abdomen. The flattened body and the position of the wings enable both sexes to travel very rapidly through bins of grain.

The head of the female is almost rectangular in shape when viewed from the front (Fig. 9), measuring about 0.43 mm. in length by 0.34 mm. in width, just posterior to the compound eyes. The head of the male is much smaller and less rectangular in shape (Fig. 10) than that of the female, measuring about 0.32 mm. in length by 0.30 mm. in width. The antennae of the male are longer than the more robust antennae of the female (Figs. 7 and 8).

The mouth parts of the male and female are very similar, except that the female structures are somewhat larger (Figs. 11, 12, 13, and 14). The mandibles (Figs. 11 and 14) have well developed bristles on the outer edges and finer bristles on the inner edges. There are three toothlike projections on each mandible. The median pair of teeth are blunt and rounded and fit into the concavity formed by the larger, sharply pointed, lateral tooth, which curves inward over them. The female mandible is about 0.13 mm. long and 0.06 mm. wide, while that of the male is approximately 0.12 mm. by 0.06 mm.

The maxillae and labium are united into a maxillolabial complex (Figs. 12 and 13). The cardo is shaped very much like the stock of a rifle, and most of it is situated inside the head capsule. The stipes is semicircular in shape and articulates with the cardo by a spherical joint. It bears a number of sensory bristles on the lateral and ventral sides. On the outer distal edge is the four-segmented maxillary palp, while the inner dorsal edge bears the triangular lacinia and the almost circular galea, which is narrow at the base and wide at the tip. Both the galea and lacinia are almost completely membranous. The lacinia has a few very fine hairs at its tip, while the galea has numerous strong bristles, some of which are borne on the tip of conelike projections. A pair of papillae-like projections, which may possibly be taste papillae, are also present on the border of the galea. The labium is connected to the head capsule by a Y-shaped submentum. The weakly sclerotized mentum, which beyond the labial palps gradually changes without any boundary into the membranous united glossae, is rectangular in shape. A two-segmented palp arises from each lateral anterior edge, and just anterior and medial to them are the paraglossae. The mentum bears several long bristles as shown in Figs. 12 and 13.

The labial palpi are two-jointed, the distal segment bearing a few long bristles. The glossae have four bristle-bearing sensory cones on the ventral side near the anterior border. In addition the anterior border and the dorsal surface are densely covered with extremely small hairs. The paraglossae lie dorsally on top of the united glossae and are more strongly sclerotized at their distal ends, which bear a row of six or seven strong, bristle-bearing cones.

The well developed, beautifully iridescent wings show practically no sign of venation in either the male or female. The prostigma and pterostigma are very small and the forewing has no basal cells. The costal margin of the forewing bears a few stiff bristles, while the anterior and posterior apical curvatures bear a marginal fringe of hairs. The hind wing has a similar marginal fringe of hairs, which extends along the anal margin of the wing as well. Both fore and hind wings are covered by fine hair over the entire surface.

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*Head and mouth parts (male and female) of Cephalonomia waterstoni Gahan.*

*CD:* cardo; *GA:* galea; *GL:* glossae (united); *LBP:* labial palp; *LC:* lacinia; *MT:* mentum; *MXP:* maxillary palp; *PGL:* paraglossa; *SMT:* submentum; *ST:* stipes.

FIG. 7. Antenna (male).

FIG. 8. Antenna (female).

FIG. 9. Head (female).

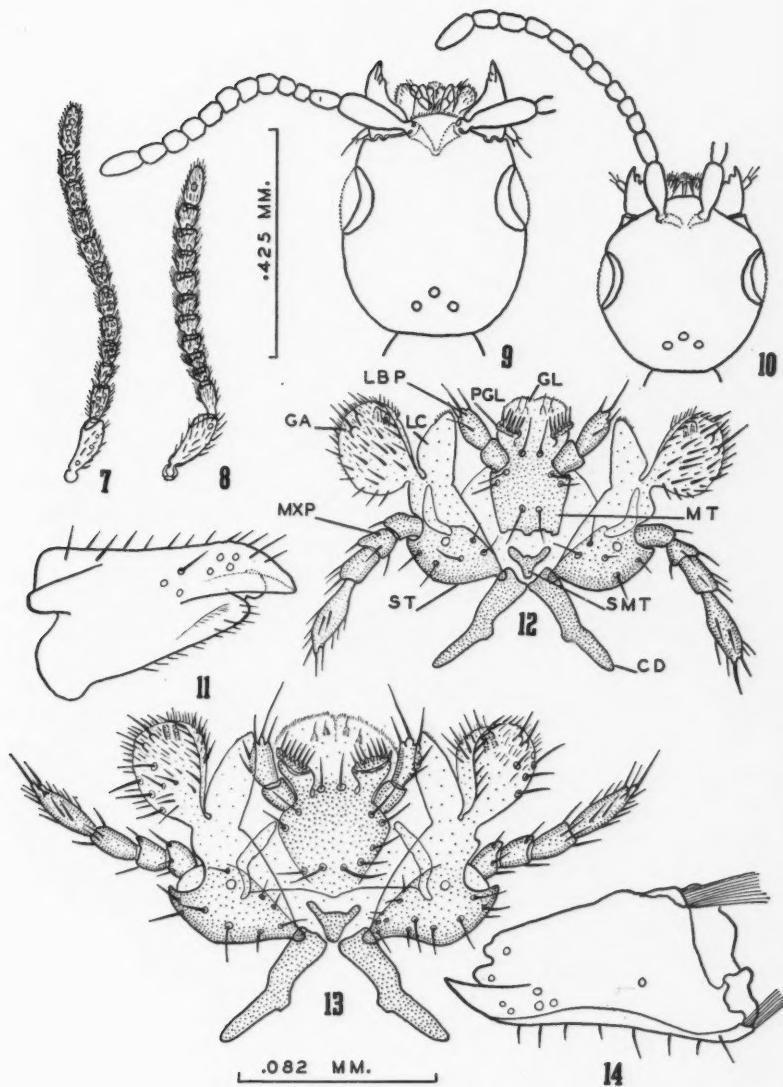
FIG. 10. Head (male).

FIG. 11. Mandible (male).

FIG. 12. Maxillolabial complex (male).

FIG. 13. Maxillolabial complex (female).

FIG. 14. Mandible (female).



The legs of the female and male are very similar in structure (Figs. 15 to 23) the male legs being slightly less robust in form. Both sexes have well developed antenna cleaners on the forelegs (Figs. 15 and 16). The cleaner is

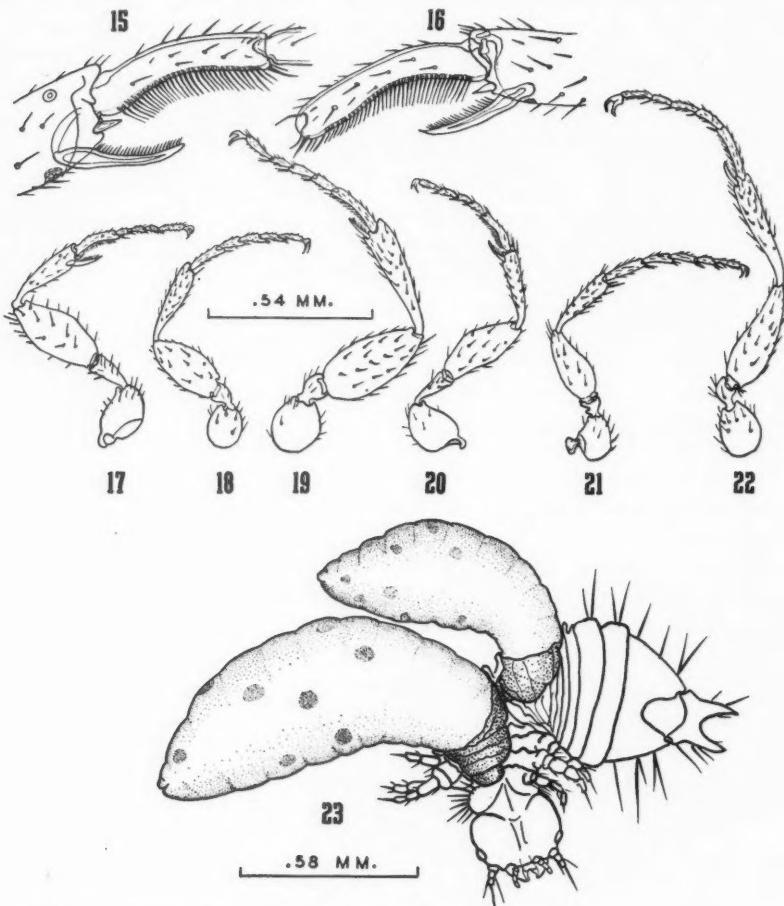


FIG. 15. Antenna cleaner (female).

FIG. 16. Antenna cleaner (male).

FIGS. 17, 18, 19. Fore-, mid-, and hind legs of female.

FIGS. 20, 21, 22. Fore-, mid-, and hind legs of male.

FIG. 23. Two larvae of *Cephalonomia waterstoni* Gahan, one full grown, the other slightly smaller, feeding on a rusty grain beetle larva.

formed partly by the proximal tarsal segment and partly by a modified tibial spur or calcar. The proximal tarsal segment is curved, and bears on its concave margin a row of long bristles, which form a comb or strigilis to clean

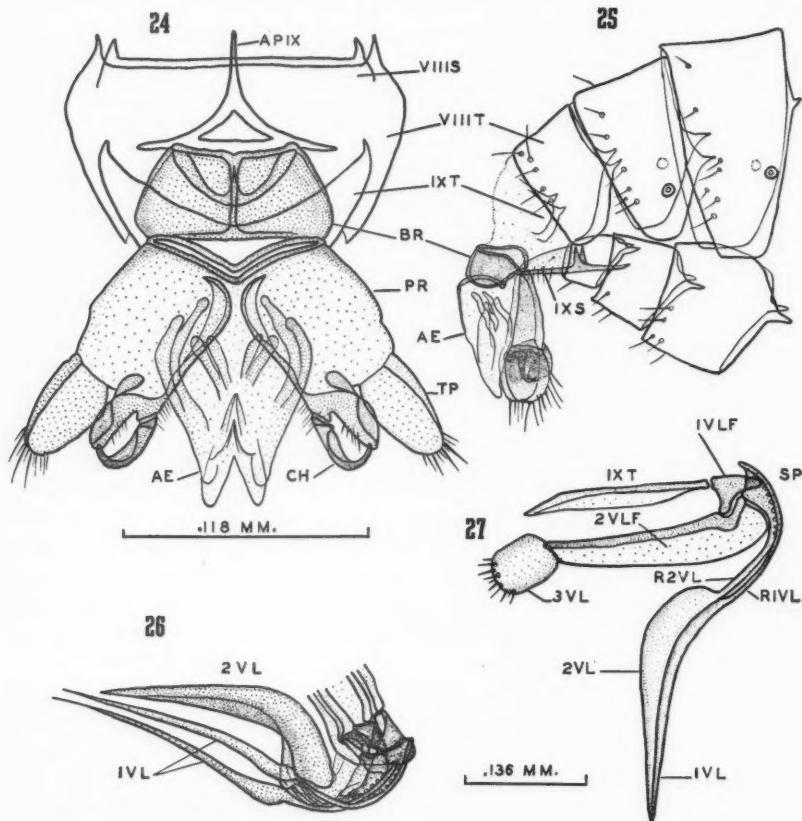
the antenna. The well developed, elongate, pectinate tibial spur is curved outward and then inward, so that its concave side faces the concavity of the strigilis. As a result the antenna is cleaned by the bristles of the strigilis and the calcar when it is drawn between them. An additional small peg-shaped spur is present on the tip of the tibia, between the articulation of the latter with the tarsus and the larger tibial spur. The femur and tibia of the hind legs of both sexes are considerably elongated and the tibiae bear long pectinate spurs at their distal ends (Figs. 19 and 22).

The shiny-black, ovate, nine-segmented abdomen is compressed dorso-ventrally. The male copulatory apparatus consists of a pair of clasping organs and an aedeagus. The phallobase, which forms the connection with the ninth segment, is a closed ring or braceletlike structure that articulates with the ninth sternite (Fig. 25). The band is narrower on the ventral side where it has a median sclerotized projection directed anteriorly. The dorsal median part of the band shows a suture where the two ends of the "bracelet" have joined. Fastened to this ringlike sclerotized band are the aedeagus and clasping organs. The aedeagus occupies a median and dorsal position, while the clasping organs are lateral and ventral to it (Figs. 24 and 25). The aedeagus viewed dorsally has the shape of a truncated cone with somewhat concave sides. Its sides show portions rather strongly sclerotized, but in the main the aedeagus appears membranous.

The clasping organs are quite complicated structures; the basal parts of parameres articulate with the phallobase at the proximal end, and distally bear the claspers and tactile plates (Fig. 25). The parameres are oblong structures lying lateral and ventral to the aedeagus. Each bears on the dorsal side at the base a bow-shaped, sclerotized ridge which, when the parameres are closed, lies close to the aedeagus. The inner sides of the parameres, which are associated with the clasping function of these organs, are strongly sclerotized, especially in their distal parts. A row of tactile bristles stands on this more strongly sclerotized area. Articulated with the inner proximal margin of this sclerotized portion is the clasper, a strongly sclerotized hook that curves laterally so that its tip can be made to close upon the apical end of the sclerotized area just described (Fig. 24). To the outside of the clasper is an arched, platelike tactile organ bearing numerous tactile bristles at its tip (Fig. 24). The length of the whole male copulatory apparatus, including the phallobase, is about 0.17 mm. The basal ring or phallobase is about 0.03 mm. wide on the dorsal side and only 0.01 mm. at its narrowest part on the ventral side. The parameres are about 0.12 mm. long, including the tactile plate, which is 0.05 mm. in length.

The female stinging apparatus in *Cephalonomia waterstoni* (Figs. 26 and 27), as in other stinging Hymenoptera, includes not only the usual parts of the ovipositor but also the lateral sclerites (quadrate plates) of the ninth tergite. The quadrate plates, which are somewhat parallelogram-shaped, are strengthened by strongly sclerotized ridges, which at the posterior ends of the plates

articulate with the triangular-shaped first valvifers (corner plates). Articulating with the first valvifers are the bow-shaped rami of the first valvulae, which connect distally to the long slender first valvulae or lancets of the sting



*Genitalia of Cephalonomia waterstoni Gahan.*

*AE:* aedeagus; *APIX:* apodeme of ninth sternite; *BR:* basal ring; *CH:* clasping hook; *PR:* paramere; *RIVL:* ramus of first valvula; *R2VL:* ramus of second valvula; *SP:* sickle-shaped plate; *TP:* tactile plate; *IVL:* first valvula; *2VL:* second valvula; *3VL:* third valvula; *1VLF:* first valvifer; *2VLF:* second valvifer; *VIIIS:* eighth sternite; *IXS:* ninth sternite; *VIIIIT:* eighth tergite; *IXT:* ninth tergite.

FIG. 24. Dorsal view of male genitalia.

FIG. 25. Lateral view of male genitalia.

FIG. 26. First and second valvulae of stinging apparatus.

FIG. 27. Right one-half of stinging apparatus.

(Figs. 26 and 27). The second valvifers (oblong plates plus sickle-shaped plates) give rise to the rami of the second valvulae, which are connected distally to the second valvulae. The latter unite to form an inverted trough,

the median stylet. The slender first valvulae or lancets slide on the lower margins of the median stylet. At the other end of the oblong plates are articulated the third valvulae, which form a sheath in which the first and second valvulae are protected when in repose. The first valvulae are approximately 0.27 mm. in length; the second valvulae are slightly shorter, while the third valvulae are very much shorter. The length of the rami of the first and second valvulae are not included in the above measurements.

The adults apparently are strong fliers, as they have been taken in ventilator traps situated at the apex of the roof of grain bins (3). Schwitzgebel and Walkden in order to determine just what species of insects actually entered grain bins, placed ventilator traps at the apex of the roof of two 1000 bu. steel bins that were tightly caulked so that the only avenue by which insects could gain entrance was through the ventilator traps. Many specimens of *Cephalonomia waterstoni* were taken in these traps.

#### Sex Ratio of *Cephalonomia waterstoni* Gahan

Since *Cephalonomia waterstoni* males were unknown, an attempt was made to find them in the cultures used in the life history studies. Two hundred live adults were sifted from the grain and placed in a 10% potassium hydroxide solution overnight. Adults treated in this manner could easily be sexed, as the genitalia could then be seen when they were placed on slides and viewed through a microscope. Of the 200 adults examined three proved to be males. From the preponderance of females and the fact that males of the species had not previously been found, it seemed that the male must be of little importance in the life cycle of the insect, and that the species must be mainly parthenogenetic in its habits.

This hypothesis was tested by rearing isolated females so that they were known to be virgins. These unmated females laid eggs, but, when their offspring were sexed, only males were found. This showed that virgin females could only produce eggs that developed into males, or in other words, that unfertilized eggs produce only males. This fact, which disproved the hypothesis advanced above, did not seem to be consistent with the fact that so few males were present in the cultures. It did not seem probable that such a low proportion of males in a species of Hymenoptera with solitary habits would be sufficient to ensure the survival of the species. It then occurred to the writer that possibly the sifting of live adults of *Cephalonomia waterstoni* from a culture that had been established for only a few weeks did not give a true picture of the sex ratio. Therefore the grain from a culture was again sifted, but this time only dead adults were taken and treated with potassium hydroxide. When these adults were sexed only 14 out of a total of 52 were found to be females. It was then perfectly clear that the ratio of females to males was far different from that brought out in the sexing of the initial 200 insects. The fact that females outnumbered males among the live adults, while the opposite was true for the dead adults, could be explained on the supposition that females are longer lived than males. In other words it

appeared that in a fairly new culture of *Cephalonomia waterstoni* not many of the females had died while many of the males had succumbed. But this explanation would hardly explain why only three males were found among the 200 live adults sexed, as it would seem probable that more than this number of males would be present in such a large sample.

In order to get a more reliable estimate of the sex ratio 22 mated female parasites were taken and kept isolated in individual rearing cages. Beetle larvae were supplied daily to the female wasps and each day the parasitized larvae were removed and the parasites reared to the adult stage and then sexed. The progeny of each female was kept separate and the number of males and females among a random sample of each female's offspring is given in Table II.

TABLE II

SEX RATIO IN THE OFFSPRING OF 22 FEMALES OF *Cephalonomia waterstoni* GAHAN

Female number	Sexed random sample from offspring of each female		
	Total number sexed	Number of males	Number of females
1	10	3	7
2	1	0	1
3	5	2	3
4	12	4	8
5	6	2	4
6	6	3	3
7	8	2	6
8	15	3	12
9	10	2	8
10	17	6	11
11	6	2	4
12	12	4	8
13	2	0	2
14	5	1	4
15	5	1	4
16	7	4	3
17	1	0	1
18	2	0	2
19	5	2	3
20	9	4	5
21	12	4	8
22	11	3	8
Totals	167	52	115

The data given in Table II suggest that the true ratio of females to males in *Cephalonomia waterstoni* is somewhere near 2 : 1.

#### Oviposition Rate of *Cephalonomia waterstoni* Gahan

Twenty-five *Cephalonomia waterstoni* females of unknown age were chosen at random from one of the culture jars. Each female was put into a small-size

rearing cage that contained three or four fourth instar larvae of *Laemophloeus ferrugineus*. For the next 10 days each female was transferred to a new container containing fresh host larvae. The larvae in each cage, after the female had been removed, were then examined and the number of parasite eggs laid during the preceding 24 hour period was determined. The results of these counts are given in Table III. This table shows that females of

TABLE III  
OVIPOSITION RECORD OF 25 *Cephalonomia waterstoni* FEMALES OF UNKNOWN AGE OVER A PERIOD OF 10 DAYS

Insect number	Number of eggs laid on successive days										Total eggs laid in 10 days	Average eggs per female per day
	1	2	3	4	5	6	7	8	9	10		
1	3	4	2	2	2	8	6	0	0	Dead	27	3.0
2	0	1	3	1	0	0	2	2	3	0	12	1.2
3	2	4	3	2	3	4	4	0	0	0	22	2.2
4	1	2	1	0	4	0	0	2	2	2	14	1.4
5	4	1	0	2	4	4	2	4	2	2	25	2.5
6	2	2	2	3	0	2	5	0	1	0	17	1.7
7	4	1	0	1	4	4	0	2	0	0	16	1.6
8	2	2	1	3	2	0	3	0	2	2	15	1.5
9	3	2	2	1	0	1	1	2	0	0	12	1.2
10	2	2	0	3	2	2	4	4	2	1	22	2.2
11	1	5	3	0	4	5	4	2	2	3	29	2.9
12	4	1	2	2	1	3	3	0	0	0	16	1.6
13	4	3	2	1	0	2	4	0	0	0	16	1.6
14	0	2	0	1	0	0	0	0	0	0	3	0.3
15	4	2	4	1	2	5	3	2	1	3	27	2.7
16	2	2	4	1	2	1	4	0	4	2	21	2.1
17	0	2	0	1	1	2	1	1	0	0	8	0.8
18	0	3	1	2	0	4	3	1	0	1	15	1.5
19	0	0	2	1	1	2	3	0	0	1	10	1.0
20	0	1	0	0	0	2	2	0	0	1	6	0.6
21	2	0	0	1	0	0	0	0	0	1	4	0.4
22	1	1	2	4	0	2	2	0	0	0	12	1.2
23	2	4	5	4	2	4	3	0	2	4	30	3.0
24	1	3	1	3	3	5	1	2	2	2	23	2.3
25	-	4	2	2	3	6	4	0	0	2	23	2.6
Totals	44	54	42	42	40	68	64	24	23	24	425	

*Cephalonomia waterstoni* laid an average of one to three eggs per day, but may lay as many as eight in a single 24-hr. period. No doubt the number of suitable host larvae present has much to do with the rate of oviposition. An attempt was made to provide sufficient suitable host material to obtain the maximum oviposition rate, but three or four host larvae crawling about in an otherwise empty container presented unnatural conditions to the introduced parasite females, which may have influenced their oviposition reactions.

However, any other method would have made successful egg counts impossible, and the data obtained at least give valid evidence of the potential oviposition rate of *Cephalonomia waterstoni*.

### Studies of the Effects of *Cephalonomia waterstoni* Infestations on *Laemophloeus ferrugineus* Populations

Twenty-five adults of *Laemophloeus ferrugineus* were put into each of four different pint mason jars filled with wheat. The jars were then put into an incubator running at 90° F. and 65 to 75% relative humidity. One month later 10 *Cephalonomia waterstoni* adults were put into two of the jars. Forty days after the parasites were introduced the contents of the four jars were screened and the insect counts that were made are given in Table IV. They

TABLE IV

NUMBER OF INSECTS SCREENED FROM FOUR TEST JARS USED IN THE FIRST EXPERIMENT TO DETERMINE THE EFFECT OF *C. waterstoni* ON POPULATIONS OF *Laemophloeus ferrugineus*

Jar number	Beetles			Adult parasites	
	Larvae	Pupae	Adults	Alive	Dead
1	3	0	711	163	178
2	4	0	502	156	202
Totals	7	0	1213	319	380
3	257	6	1572	0	0
4	216	4	1209	0	0
Totals	473	10	2781	0	0

show that the presence of the parasite had very significantly retarded the increase of rusty grain beetles. This retardation is still more evident when a comparison of the insect populations not removed by screening is made. One hundred kernels of grain chosen at random were dissected and the record of the different stages of *Laemophloeus ferrugineus* found is given in Table V, which also gives the estimated number of insects left per jar after screening.

Table VI compares the total *Laemophloeus ferrugineus* populations of the four jars. These totals were derived by adding the number of insects actually removed to the estimated totals of those not removed.

It can be seen by the summarized data in Table VI that the introduction of 10 adults of *Cephalonomia waterstoni* into each jar destroyed enough rusty grain beetles in 40 days to reduce their number to approximately one-third of that found in the corresponding control jars. These results were so striking that the experiment was repeated. This time, however, instead of adding 10 parasites to *Laemophloeus ferrugineus* cultures one month old, 25 parasites

TABLE V

NUMBER OF *Laemophloeus ferrugineus* DISSECTED FROM 100 KERNELS OF WHEAT, AND THE ESTIMATED POPULATION LEFT IN THE RESPECTIVE JARS AFTER SCREENING

Jar number	Number of <i>L. ferrugineus</i> dissected from 100 kernels of wheat			Estimated number of <i>L. ferrugineus</i> left in each jar		
	Larvae	Pupae	Adult	Larvae	Pupae	Adults
1	6	1	3	720	120	360
2	7	0	0	840	0	0
Totals	13	1	3	1560	120	360
3	22	3	3	2640	360	360
4	19	1	2	2280	120	240
Totals	41	4	5	4920	480	600

TABLE VI

TOTAL *Laemophloeus ferrugineus* POPULATIONS OF THE FOUR TEST JARS USED IN THE FIRST EXPERIMENT TO DETERMINE THE EFFECT OF *Cephalonomia waterstoni* ON *Laemophloeus ferrugineus* POPULATIONS

Jar number	Total number of beetles per jar	Jar number	Total number of beetles per jar
Parasites present:		No parasites:	
Jar 1	1914	Jar 3	5195
Jar 2	1346	Jar 4	4069
Total	3260	Total	9264

were added to cultures that were only 13 days old. The insect counts and kernel dissections were made 35 days later instead of 40 days. The results obtained are shown in Tables VII, VIII, and IX. Again the results are very significant, although the reductions obtained in beetle populations were not quite so great as in the first experiment.

These two experiments show that the parasitic wasp *Cephalonomia waterstoni* increases in numbers very rapidly in wheat infested with the rusty grain beetle under laboratory conditions, and that the presence of the parasite causes a marked retardation in the increase of the beetle population. The measure of control that would result from the introduction of this wasp into infested wheat in commercial storage is purely speculative. However, this work definitely shows that this particular parasite can easily be reared in tremendous numbers under laboratory conditions. It also suggests that the introduction of large numbers of the parasite into heavily infested grain, or periodically into infested mills and warehouses, might have far-reaching beneficial effects.

TABLE VII

NUMBER OF INSECTS SCREENED FROM THE FOUR TEST JARS USED IN THE SECOND EXPERIMENT  
TO DETERMINE THE EFFECT OF *Cephalonomia waterstoni* ON  
POPULATIONS OF *Laemophloeus ferrugineus*

Jar number	Beetles			Adult parasites	
	Larvae	Pupae	Adult	Alive	Dead
1	0	0	116	132	136
2	1	0	165	103	114
Totals	1	0	281	235	250
3	31	1	356	0	0
4	18	0	363	0	0
Totals	49	1	719	0	0

TABLE VIII

NUMBER OF *Laemophloeus ferrugineus* DISSECTED FROM 100 KERNELS OF WHEAT, AND THE  
ESTIMATED POPULATION LEFT IN THE RESPECTIVE JARS AFTER SCREENING

Jar number	Number of <i>L. ferrugineus</i> dissected from 100 kernels of wheat			Estimated number of <i>L. ferrugineus</i> per jar		
	Larvae	Pupae	Adults	Larvae	Pupae	Adults
1	2	0	0	240	0	0
2	13	0	0	1560	0	0
Totals	15	0	0	1800	0	0
3	12	0	1	1440	0	120
4	14	1	0	1680	120	0
Totals	26	1	1	3120	120	120

TABLE IX

TOTAL *Laemophloeus ferrugineus* POPULATIONS OF THE FOUR TEST JARS USED IN THE SECOND  
EXPERIMENT TO DETERMINE THE EFFECT OF *Cephalonomia waterstoni*  
ON POPULATIONS OF *Laemophloeus ferrugineus*

Jar number	Total number of insects per jar	Jar number	Total number of insects per jar
Parasites present:		No parasites:	
Jar 1	356	Jar 3	1948
Jar 2	1726	Jar 4	2181
Total	2082	Total	4129

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THE BIOLOGY OF *LAEMOPHLOEUS FERRUGINEUS* (STEPH.)<sup>1</sup>BY R. OMAR RILETT<sup>2</sup>

## Abstract

Life history and morphological studies were made on *Laemophloeus ferrugineus* (Steph.), a coleopterous pest of stored grain and other products.

Temperature greatly affected the rate of development of *L. ferrugineus*. At a relative humidity of 75%, eggs at 80° F. hatched in four to five days, at 90° F. in three to four days, and at 100° F. in two to three days. Similarly, the period from hatching of the egg to the emergence of the imago at 70° F. was from 69 to 103 days, at 80° F. from 26 to 38 days, at 90° F. from 19 to 33 days, and at 100° F. from 17 to 26 days. First instar larvae did not survive at a temperature of 110° F.

An increase in relative humidity within the range from 50 to 75% accelerated development during the larval feeding period. Above 75% relative humidity there was no significant acceleration of development. Mortality was very high at relative humidities below 50%—all larvae failing to develop at a relative humidity of 25%. At 90° F. the period from the hatching of the egg to the emergence of the imago at 50% relative humidity was from 28 to 42 days, at 65% relative humidity from 23 to 33 days, at 75% from 19 to 25 days, at 90% relative humidity from 18 to 25 days, and at 100% relative humidity from 18 to 27 days. The optimum environmental condition for the development of *L. ferrugineus* was from 90° F. to 100° F. at a relative humidity of 75% or higher.

*L. ferrugineus* populations increased more rapidly in whole rye and wheat grain than in the same materials when they were coarsely ground. Just the opposite was true in the case of oats, barley, corn, sunflower, flax, and soybeans. Whole kernels of rye, wheat, corn, and rice were decreasingly susceptible to injury in the order named, while whole kernels of oats and barley, and the seeds of sunflower, flax, and soybeans were practically free from injury by *L. ferrugineus* at humidity levels normally occurring in stored grains and seeds. Although first instar larvae did gain access to the wheat germ of grain described commercially as being "whole, sound, and undamaged", they were unable to successfully attack whole wheat kernels that had no breaks in their bran layers. The breaks need only to be microscopic in size to allow penetration by the larvae.

## Introduction

The rusty grain beetle, *Laemophloeus ferrugineus* (Steph.), formerly known as the rust-red grain beetle, belongs to the family Cucujidae and was described by Stephens about 1845. Leng (6) listed *Cryptolestes* as a subgenus of *Laemophloeus* and designated the insect as *Laemophloeus ferrugineus* (Steph.). Casey (4), on the other hand, maintained that *Cryptolestes* is a very distinct and well characterized genus, and Sheppard (10) appears to agree with Casey, since he designated the insect as *Cryptolestes ferrugineus* Steph. In the literature, however, Leng's classification is most often used, and the insect is referred to as *Laemophloeus ferrugineus* (Steph.).

Leng listed *ferrugineus* (Steph.), *testaceus* (Payk.), and *monilicornis* (Steph.) as synonymous specific names for this species.

<sup>1</sup> Manuscript received February 4, 1949.

This work, which was instigated by Dr. H. E. Gray, In Charge, Stored Product Insect Investigations, Ottawa, and Dr. B. N. Smallman, Entomologist, Board of Grain Commissioners, for Canada, was begun at the University of Western Ontario, London, Ont. and completed at the University of Wisconsin, Madison, Wis. The work at the latter university was supported in part by the Wisconsin Alumni Research Foundation.

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A comprehensive survey of the literature shows that very little has been reported about the biology of the rusty grain beetle, although many references to its presence and importance exist. Casey (4) and Wheeler (12) gave its distribution as cosmopolitan and the literature certainly gives ample supporting evidence for this statement. Only two references to its biology were found: Belyaev, Shesterikova, and Popov (2) and Sheppard, E. H. (10). The first article deals with the insect as a pest of oil seeds in Russia, while the second is concerned with the biology of the insect in relation to *Trichogramma minutum* parasite rearing work. Sheppard's attention was attracted to the beetle when it became established in the incubators used for rearing the Angoumois grain moth at Colorado State College. It fed upon the eggs of the grain moth that were used in rearing *Trichogramma minutum*, a parasite of codling moth eggs.

In the United States the damage to stored grains by primary grain pests such as the granary weevil, *Sitophilus granarius* (Linn.), the Angoumois grain moth, *Sitotroga cerealella* (Oliv.), the rice weevil, *Sitophilus oryzae* (Linn.), and the lesser grain borer, *Rhyzopertha dominica* (Fab.), is so tremendous that the injury caused by *Laemophloeus ferrugineus* is more or less overlooked. For example, no specific reference was found on its occurrence in Wisconsin, yet upon investigation it was found in goodly numbers in the University of Wisconsin's feed storage building, and therefore it is likely prevalent throughout the state. It has been reported from most of the 48 states, however, and Farrar and Flint (5) report it widespread in stored corn in Illinois. A recent survey carried out in California by Linsley and Michelbacher (7) showed that *Laemophloeus ferrugineus* was present in 3 out of 42 insect-infested granaries examined in the Sacramento Valley; 9 out of 37 in the San Joaquin Valley; 7 out of 33 in the Coastal Region; and 5 out of 16 in the Southern Interior. These workers listed *Laemophloeus ferrugineus* among the secondary pests of grain. It was their belief that this insect rarely attacks whole grain at the moisture level that prevails in normal storage, but that it is associated with the primary pests and follows closely upon their attack. Although this may be true for California conditions it does not hold for the entire continent, as will be brought out later.

A severe outbreak of granary pests occurred in flour mills in the Russian Union in 1937 and a survey was carried out in July of that year in Moscow and the province of Voronezh (11). Of the pests found, *Laemophloeus testaceus* Fab., *Laemophloeus ferrugineus* (Steph.), and *Tribolium confusum* Duv., were the most injurious and were abundant in all the mills examined. The first two had previously been considered as unimportant and restricted to the south of the Russian Union. In the mills they occurred in tunnels in crusts of flour that formed on the walls of certain parts of the equipment as a result of the contact of the warm flour with the cold surface of the walls and the condensation of moisture there. *T. confusum* infested thicker crusts than those in which *Laemophloeus* occurred.

In normal times Canadian grains move forward steadily, allowing little opportunity for insects to become established, and, in the western provinces particularly, the severe winter temperatures have kept insect infestation of stored grain practically negligible. Yet between 1939 and 1944 the rusty grain beetle became a major grain pest in Canada, and at that time ranked as the most important insect pest of stored grain in Western Canada (3).

The phenomenal increase in rusty grain beetle infestations in Western Canada was intimately associated with the temporary storage of wheat during World War II. The types of storage used and typical cases of *Laemophloeus ferrugineus* infestations were described by Dr. B. N. Smallman in a paper entitled, *Entomological Aspects of Wartime Grain Storage* in the May 1945 issue of *Grain*.

#### General Methods

Small, seamless, metal,  $\frac{1}{4}$  oz. salve boxes, with a  $\frac{1}{2}$  in. hole punched in the lid were used for individual rearing cages. The hole in the lid was covered with silk bolting cloth, held in place by Duco household cement. These boxes proved very satisfactory for rearing and examining the larvae. Each box was numbered to prevent errors that might have occurred if the lids had been numbered and then accidentally interchanged.

Two larger sizes of metal rearing cages (3 oz. and 6 oz.) were used in some of the experiments. The cages were arranged on wire mesh trays that could easily be removed from a metal rack on which they were supported while in the incubator. In those experiments where a definite constant humidity was maintained, the cages were supported by three-tiered metal trays that were built to fit into desiccators (9).

Thermostatically controlled incubators, provided with electric fans to keep the warmer air from becoming stratified at the top of the chambers, were used. Temperatures within one Fahrenheit degree of that desired were maintained.

A fairly uniform relative humidity was provided in each incubator by two jars containing water and provided with cheesecloth wicks extending up to the bottom shelf of the incubator.

Eggs or adults for the various experiments were obtained by screening heavily infested, moldy wheat through a four-layered, brass frame, 5 in. sieve set. The sieves, starting at the bottom, were of a mesh to give 80, 60, 40, and 20 openings per linear inch respectively, in this order. The grain remained on the top screen, the adults collected on the 40-mesh screen, and the eggs on the bottom screen. The 60-mesh screen was included to remove some of the broken particles of wheat that were small enough to come through the coarser sieves. Finer debris, and mites when present, passed on through the 80-mesh screen to the bottom and were destroyed after each screening. This procedure prevented the accumulation of debris in the culture, and at the same time provided a very efficient method for the control of mites.

No natural enemy of the beetle became troublesome with the exception of the common yellow house ant (*Monomorium pharaonis*). While some renovation work was being carried out in the laboratory the cultures were not inspected closely for a period of a few weeks until it was noticed that ants had invaded the incubators, eaten their way through the bolting cloth into the jars, and were carrying off the larvae of *Laemophloeus ferrugineus* at a rapid rate. Several thousand ants were present and a procession of ants, each ant with a larva grasped between its mandibles, was observed emerging from one of the culture jars.

They were quickly brought under control by thoroughly cleaning out the incubator and painting its legs, floor, and walls with a solution of D.D.T. in oil. Tree Tanglefoot was smeared around the openings in the lids of the jars and cages. These measures brought the ants completely under control, and they gave no further trouble.

In life history studies and in experiments where the time of each molt was to be recorded, a single thick cross section of a wheat kernel through the germ region was used as food in each rearing cage. This food was chosen for the following reasons: (1). Previous observations had shown that the larvae had a strong preference for the embryo of wheat. (2). No opportunity was provided for the larvae to burrow into the food and thus become hidden from view. (3). Larvae fed on wheat germ developed more rapidly and more uniformly than those fed on any other portion of wheat, or even on whole wheat. (4). The larvae showed no inclination to wander about when provided with this food. (5). Survival was practically 100% when wheat germ was provided. (6). Sometimes wheat germs are found that are relatively dark in color. These seem to be less favorable as larval food, for development is noticeably retarded when they are fed. The use of cross sections facilitates the detection of these undesirable germs and permits their immediate replacement by another cross section. (7). The cast exuviae were easy to find, which was not the case when meal, flour, or whole wheat was used as food.

A very simple method for the accurate sexing of live beetles was devised. The beetles to be sexed were put in a rearing cage and the cage with its lid removed was placed on finely chopped ice held in a Petri dish. As soon as the floor of the cage became chilled, the beetles became inactive and completely helpless. They could then be studied under the binocular microscope even more satisfactorily than mounted specimens, as the legs, wings, etc., could be moved about by small needles without any danger of breaking them off. The males and females were determined by characteristic differences in the appearance of their antennae, mandibles, and genitalia. In the few instances where doubt remained as to the correct sex, it was necessary to apply light pressure to the ventral part of the abdomen with a pair of very small blunt forceps. If the beetle were a female the "stili" and "substitutional ovipositor" were extruded as shown in Fig. 10. If carefully carried out, this procedure did not harm the beetle.

### Life History of the Rusty Grain Beetle, *Laemophloeus ferrugineus* (Steph.) at 90° F. and 75% Relative Humidity

Eggs are deposited by *Laemophloeus ferrugineus* females in small crevices, furrows, fractures, or holes in the wheat kernels, in spaces between the kernels, or among the detritus, by means of the "substitutional ovipositor" (Fig. 10), consisting of the telescoped caudal segments of the abdomen. During oviposition these segments, which normally are retracted within the abdomen, are protruded posteriorly and extended deep into the groove in which the egg is placed. The terminal segment bears a pair of "styli", which probably act as manipulators, helping to orient the egg into the crevice. Eggs have been found, upon dissection of the wheat kernel, in the germ region just under the outer layers of the seed coat, showing that they had been placed there by the insertion of the "substitutional ovipositor", through the small opening often present in the germ end of the wheat kernel. Many eggs are found in the spaces between the individual kernels of grain.

The eggs hatch in three to four days after oviposition. Just prior to the emergence of the larva its segmentation is dimly perceptible through the chorion. A series of undulating movements, caudocephalad, are set up by the larva, and the chorion is broken by the pressure of the larva's head capsule on one end of the egg. The larva continues this activity until its head emerges. It crawls out head first, pulling with its legs and at the same time bending backward and forward, until its attempt to free itself from the shell is successful. The empty egg shell has a very pronounced iridescence. Occasionally it adheres to the larva for some time, being drawn along with the larva as it goes in search of food.

Soon after hatching the larva sets out in search of suitable food. It shows a marked avidity for the wheat germ and if this portion of the wheat is available the larva will invariably be found feeding on it. There is sufficient food in the germ of one wheat kernel to carry the larva through its developmental stages at 90° F. and 75% relative humidity, but at lower humidities or at lower temperatures the amount of food consumed is greater. The larvae also feed on the endosperm, especially in heavily infested grain that has been extensively degерmed by earlier generations of the insect. In such cases the entire kernel may become hollowed out, leaving only the outer seed coats as an empty shell.

The larva molts four times, the last molt revealing the pupa (Figs. 28 to 36). The first larval stadium varies from three to four days, about 65% of the first instar larvae having a stadium of four days. The second stadium varies from two to five days, about 45% of the second instar larvae having a stadium of two days and about the same percentage having a stadium of three days. The third stadium is about the same length as the second, while the fourth stadium is much longer, the last two days being spent in an inactive prepupal stage. This stadium varies from five to eight days, the usual period being six or seven days.

During larval development, if the food supply is satisfactory, the larva remains within its burrow, which becomes larger as the wheat germ is consumed. The fecal material and molted exuviae are pushed out of the excavation through the opening used by the larva in gaining access to the wheat germ or that through which the egg was deposited. Larvae may sometimes leave their burrows and wander to other kernels of grain in search of more favorable food. The helpless prepupal or pupal stage is often attacked and devoured by a younger relative that enters its burrow. Young larvae feeding on prepupae and pupae have often been observed after the removal of the seed coat of a kernel of wheat so as to expose the larval burrow.

In a wheat grain habitat the larvae normally pupate within the cells that are left after the consumption of the wheat germ. Before entering the quiescent prepupal stage they effectively close the openings of their burrows with excrement and debris sealed together with silken threads. The caudal end of the larva then becomes stuck to some part of the burrow by an exudation from the anus and the anterior portion becomes more or less supported in a hammock of silk threads that are laid down during the lateral swaying of the anterior end of the body, its caudal end remaining anchored. This hammock is very simple and consists of only a few threads that serve to hold the prepupa in place. Some larvae pupate in the spaces between the kernels of grain and in hollowed-out spaces in the grain detritus.

If only a thin cross section of wheat is used as food in the rearing containers, the full-grown larvae crawl restlessly about in search of suitable places to pupate. However, if a little earth is added to the container, each larva hollows out a small cell and pupates as it would in grain. If a few bran flakes are added it cements some of these together to form a dome under which it enters the prepupal stage.

The pupa, with the dorsal portion of the prothorax appearing first, emerges from the last larval exuviae through the anterior dorsal region of the old larval exoskeleton, leaving the old head capsule attached to the rest of the exuviae on the ventral side. Then by a series of expansions and contractions of the emerging pupa's thorax and abdomen, and by a series of backward and forward movements of the abdominal segments, the exuviae is shunted caudad. The molting process is facilitated by molting fluid. During molting and immediately afterward the abdomen shortens and becomes more or less triangular in shape. The pupal period lasts about four days. On the third day the white pupa changes to a light tan, the mandibles becoming colored first.

When the adult emerges, the old integument of the pupa is sloughed off in much the same way as in the ecdysis of the larva. After the legs and wings break free, the very thin, transparent exuviae is shoved caudad by the legs and the shunting movements of the abdomen. The last segments, which later are telescoped into the abdomen, are also protruded to aid in casting off the exuviae. Shortly after emergence the second pair of wings are extended for a time and then folded beneath the elytra. The adult is of a light tan color when it emerges but changes to a rusty brown within a day or two.

Adults mate in one or two days after emergence and oviposition starts shortly thereafter. Eggs have been observed that were laid by females only two days old. When the male recognizes a female that is physiologically ready to mate, he turns and follows her. He rapidly overtakes her and follows along with his head touching the tip of her abdomen until she stops. He then strokes her elytra with his antennae and nudges her along the sides and end of the abdomen with his head; sometimes he crawls upon her back as well. Then he turns around and backs up, often backing in the wrong direction so as to miss her entirely or to come in contact with the side of her body or even against her head. During all this the female remains quiet; the only movements noticeable are the flickering of her antennae. The male persists in his trials to contact the end of her abdomen, and when he succeeds, shoves strongly backward. In a few seconds they become very tightly coupled together, the ends of the abdomens touching with the tips of the male's elytra usually resting upon those of the female. One pair kept under observation for a considerable period of time was observed to remain together in copulation for 105 min. after which they became separated for 20 min. They then became coupled for a second period of 35 min. This was followed by a third copulation period of 95 min. This same pair were observed copulating again the following day. Other copulating pairs that have been observed showed similar mating habits.

The adults feed on damaged kernels and wheat dust. After an infestation has been established the favorite feeding sites are the burrows in which the larvae have developed and from which the adults have eaten their way to freedom. They return to these burrows when hungry and feed on the remaining portions of germ or endosperm.

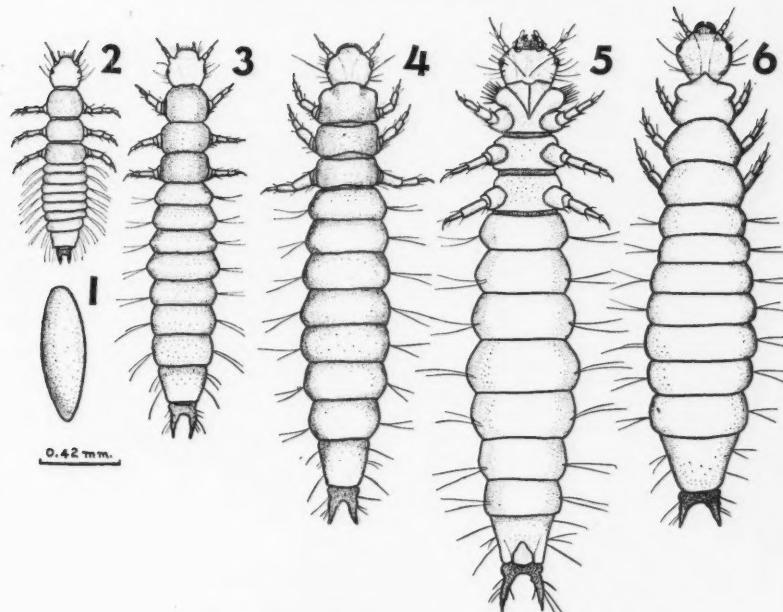
#### Life Cycle Stages of *Laemophloeus ferrugineus* (Steph.)

##### *The Egg (Fig. 1 and Fig. 38)*

The eggs are quite large in relation to the size of the insects that lay them and when isolated on a clean dark surface are quite easily seen with the naked eye. They are about three and one-half times longer than wide with one end slightly more pointed than the other. The dimensions of 10 typical eggs are given in Table I.

The eggs measured varied in length from 0.68 mm. to 0.81 mm., giving an arithmetical average length of 0.76 mm., while the variation in width was from 0.20 mm. to 0.30 mm., with an arithmetical average of 0.23 mm. Occasionally long thin eggs or short wide ones were encountered that did not fall within the range of those measured.

The eggs are white in color and moderately translucent, the embryo being dimly visible through the chorion prior to eclosion. When the eggs are first laid the chorion is easily broken, even when carefully handled with a squirrel's hair brush. The empty egg shell has a very pronounced iridescence. Occasionally it adheres to the larva for some time, being drawn along with the larva as it goes in search of food.



Egg and larval instars of *Laemophloeus ferrugineus* (Steph.)

FIG. 1. Egg.

FIG. 2. First instar, larva one day old; dorsal view.

FIG. 3. Second instar, larva eight days old; dorsal view.

FIG. 4. Third instar, larva 12 days old; dorsal view.

FIG. 5. Fourth instar, larva 18 days old; ventral view.

FIG. 6. Fourth instar, larva 20 days old (prepupa); dorsal view.

TABLE I

MEASUREMENTS OF 10 TYPICAL EGGS OF *Laemophloeus ferrugineus* (STEPH.)

Egg number	Length in mm.	Width at widest point in mm.
1	0.78	0.20
2	0.78	0.20
3	0.71	0.30
4	0.78	0.23
5	0.78	0.20
6	0.78	0.20
7	0.75	0.23
8	0.68	0.27
9	0.81	0.20
10	0.78	0.23
Average	0.76	0.23

*The Larva (Figs. 2 to 6)*

The newly emerged, crystal white larva is slightly longer than the egg. The head capsule and caudal hooks very soon become light tan in color. There are four instars and a prepupal stage.

The fully grown larva is roundish, robust, and slightly compressed dorso-ventrally when well fed, but greatly flattened if undernourished. The comparative sizes of the four instars are shown by Figs. 2 to 6, inclusive. The head and thoracic segments of the fourth instar are narrower and shorter than the segments of the abdomen, which become progressively wider posteriorly until the fourth segment, then gradually taper caudad to the terminal segment, which bears the caudal hooks. These hooks are very efficient ambulatory aids in the backward progression of the larva in burrows or crevices. The abdomen of the larva is first lengthened so as to extend the caudal hooks back farther in the crevice. Then the hooks are bent dorsad and their pointed tips anchored into a groove or onto a projection in the crevice. The abdomen is then shortened and at the same time the hooks are bent still farther dorsad. Both of these movements cause the larva to be pulled in a backward direction. The larva may also push backward with the three pairs of well developed thoracic legs in order to aid in this movement.

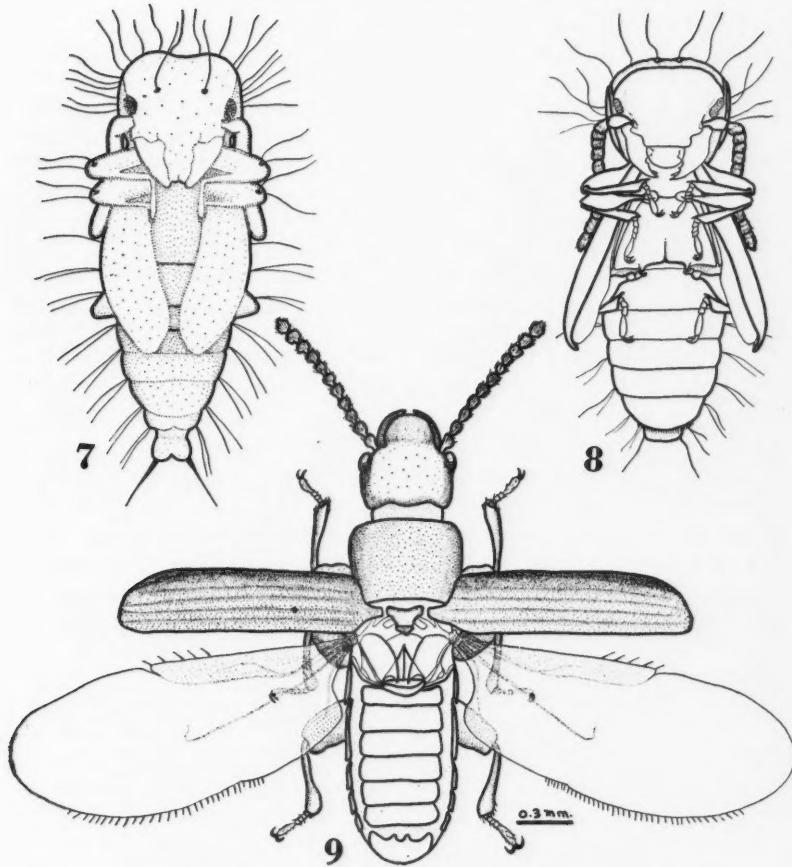
The mouth parts of the larva are very similar to those of the adult (Figs. 14 to 20), as might be expected from the similarity of their feeding habits.

On the anterior lateral margin of the prothoracic segment are two papillae, one on each side. Each papilla, which is first noticeable in the third instar and very pronounced in the fourth, is crowned by a tuft of whitish spines from which silken threads seem to originate. Silken threads appear to issue from both papillae simultaneously, not in sufficient quantity to spin a cocoon but only enough to form a network, somewhat spider-web-like, which helps hold together flakes of bran, debris, fecal pellets, etc., in a makeshift shelter.

*The Pupa (Figs. 7 and 8)*

The young pupa is white in color, with the exception of the compound eyes, which appear as dark brown spots on each side of the head. The mandibles soon become light tan in color, and about the third day after pupation (at 90° F.) the whole pupa begins to change to a light tan, gradually becoming darker until the emergence of the beetle. At 80° F. this color transition takes place from the fourth to the sixth day after pupation. The pupa is enclosed in a thin transparent integument, which is molted at the time the adult emerges.

The shape of the pupa is somewhat triangular. The future adult head lies ventrad to the prothorax, with the mouth parts directed caudad. Legs, wings, and antennae are folded neatly against the body. The wings originate dorsally, but extend laterally and ventrally so that they cover a large portion of the ventral surface of the pupa, leaving the two pairs of forelegs uncovered while covering the hind pair. The antennae extend laterally from the area



*Pupal and adult stages of Laemophloeus ferrugineus (Steph.)*

FIG. 7. *Pupa, two days old; ventral view.*

FIG. 8. *Pupa, six days old; ventral view.*

FIG. 9. *Dorsal view of female, with wings extended.*

between the eyes and the base of the mandibles, then dorsally and posteriorly, lying close to the wings, just dorsal to the forelegs.

#### *The Adult (Figs. 9 and 23)*

When the beetle first emerges the head, antennae, thorax, and legs are light amber in color and the mandibles reddish-brown. The ventral segments of the abdomen are also a light amber with the conjunctivae colorless, as are all the other conjunctivae of the body. The elytra are translucent white and the flying wings a transparent white, the former turning to reddish-brown within a few hours.

A condensed description of the adult is as follows: Beetles depressed, elongate; antennae 11, segmented, elongate, last three segments slightly enlarged, nearly as long as elytra; scutellum distinct; elytra rounded at tip and covering the abdomen, emarginate, striate, punctate, slightly longer than head and thorax together; front coxal cavities widely separated; anterior coxal cavities broadly and completely enclosed by the sterna, merely a fine suture between each side piece and the median lobe; front coxae rounded, not prominent; hind coxae widely separated, transverse; abdomen with five free ventral segments, unequal in length, the first segment being longer and apparently the result of a fusion of the embryonic first and second abdominal sternites; legs rather short; femur large; tibia slender, terminated by two spurs; tarsi five-segmented with the exception of the male hind tarsi, which are four-segmented; head and thorax finely punctured, the latter narrowed behind, sides curved sinuate near hind angles, which are sharp and prominent.

Blatchley in his key to the Coleoptera of Indiana described the males of the genus *Laemophloeus* as having the middle and hind tarsi four-segmented, while Sheppard (10) stated that the tarsi of both the males and females of *ferrugineus* are all four-segmented. Upon careful examination both these statements appear to be incorrect, the tarsal formula of the female being 5-5-5 and of the male 5-5-4 (Figs. 24 to 27). Furthermore, Sheppard described the hind coxae as "nearly contiguous, transverse", which is not descriptive of the

*Morphology of Laemophloeus ferrugineus (Steph.)*

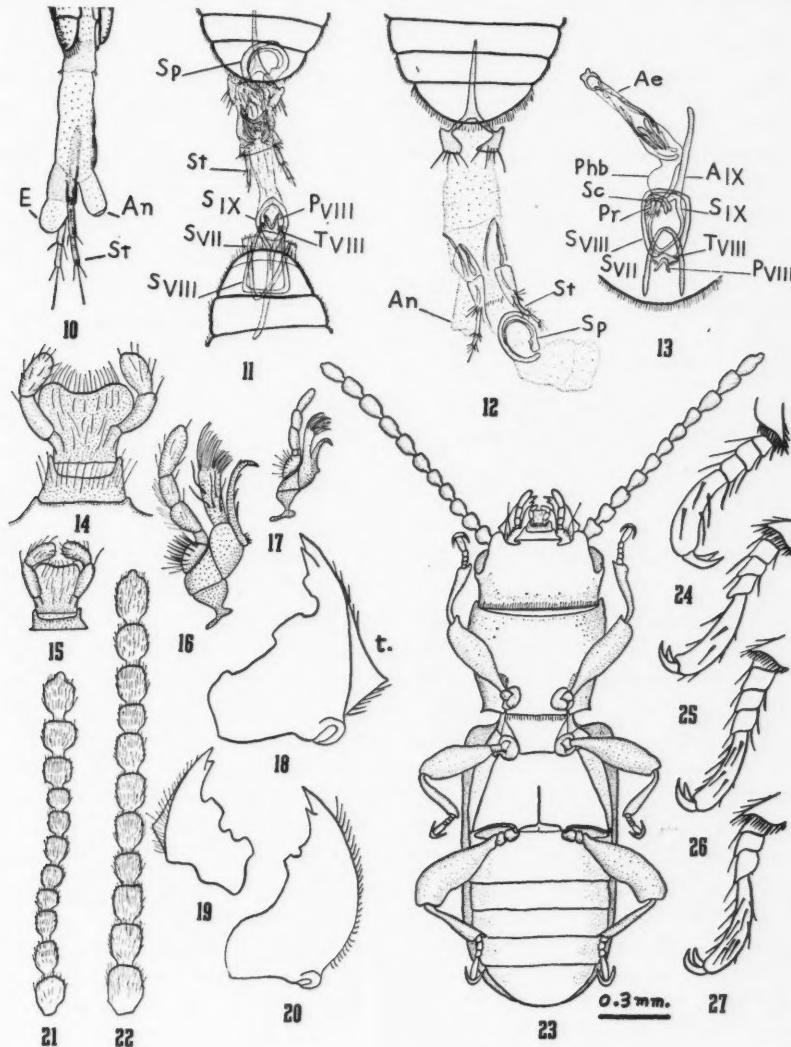
FIGS. 10 to 13. *Genitalia of Laemophloeus ferrugineus.*

*Ae:* aedeagus; *An:* anus; *AIX:* apodeme on sclerotization of the ninth abdominal segment; *E:* egg exit and female genital opening; *Phb:* phallobase; *Pr:* parameres; *PVIII:* process of eighth tergite; *Sc:* sclerotization (possibly in the walls of the genital chamber); *Sp:* sclerotization of spermatheca; *St:* stylus; *SVII:* sclerotization of seventh abdominal segment; *SVIII:* sclerotization of eighth abdominal segment; *SIX:* sclerotization of ninth abdominal segment; *TVIII:* tergite of eighth abdominal segment.

- FIG. 10. Caudal end of female with genitalia extended (lateral view).
- FIG. 11. Genitalia of a copulating pair of beetles (beetles have been pulled apart slightly).
- FIG. 12. Female genitalia extruded from the abdomen.
- FIG. 13. Male genitalia within abdomen (aedeagus is bent out of natural position).
- FIGS. 14-20. Mouth parts of *Laemophloeus ferrugineus*; *t* = toothlike projection.
- FIG. 14. Labium, adult.
- FIG. 15. Labium, fourth instar.
- FIG. 16. Maxilla, adult.
- FIG. 17. Maxilla, fourth instar.
- FIG. 18. Mandible, adult (male).
- FIG. 19. Mandible, fourth instar (male).
- FIG. 20. Mandible, adult (female).
- FIG. 21. Antenna, female.
- FIG. 22. Antenna, male.
- FIG. 23. Adult male, ventral view.
- FIG. 24. Middle tarsus, male; five-segmented.
- FIG. 25. Front tarsus, male; five-segmented.
- FIG. 26. Hind tarsus, female; five-segmented.
- FIG. 27. Hind tarsus, male; four-segmented.

strain used in these investigations, as the hind coxae were actually more widely separated than the anterior ones, although they were decidedly transverse (Fig. 23).

The male mandible (Fig. 18) differs greatly from that of the female (Fig. 20), the former having a toothlike projection (Fig. 18, *t*) on the lateral ventral side near the base. The male's antennae are, on the average, longer than the female's, with the terminal three segments relatively not so enlarged (Figs. 21



and 22). The thorax tends to be more contracted behind, and its maximum width relatively greater in the male; also the head of the male tends to be somewhat larger than that of the female.

In order to determine the proportion of males to females in a normal adult population, 125 beetles were sexed. Of these, 48 proved to be males and 75 females, or 61.6% females and 38.4% males. The percentage of females from this count is not quite as high as that found by Sheppard who reported that 75% of adults are females.

The male phallus comprises a single median intromittent organ of tubular form (Fig. 13). The ninth segment of the abdomen retracts into the eighth, and the eighth into the seventh (Fig. 13). During coition these segments, which are terminated by the tubular aedeagus, are protruded, the intromittent organ being inserted deeply into the genital chamber of the female (Fig. 11).

A copulating pair in a rearing cage may readily be studied if the cage is placed on ice. Then with two small forceps the beetles may be pulled apart very slowly while observations are being made through the binocular microscope. As the adults are pulled apart, the female and male genitalia are drawn from within the female's genital chamber. The aedeagus may be seen inserted deep into the female's genital tract, which explains why the two beetles are so firmly attached to one another during coition (Fig. 11).

Styli are present on the ninth abdominal segment of the female (Figs. 12, 11, and 10) but are never present in the male.

#### Flight Habits of *Laemophloeus ferrugineus*

Sheppard reported that adults, when they attempted flight, were unable to clear the rim of a Petri dish that was one-half inch in height. This is contrary to observations made during the present investigations, as the writer has watched adults fly out of the metal rearing cages, which required a minimum takeoff angle of 25° in order to clear the rim of the cage. This is a greater angle than would be necessary to clear the rim of the Petri dish described by Sheppard. On Aug. 8, 1944, two beetles were observed to fly up to a height of 5 ft. above the window sill in a laboratory room where the insect was being studied. The temperature at the time was 86° F. The beetles were observed during the whole flight and they rose almost vertically for the whole distance. It is therefore quite evident that they are relatively good fliers when the temperature is high. This conclusion agrees with many succeeding observations that show, however, that at temperatures of 70° F. or below the beetle is relatively inactive.

While considering the flight habits of this beetle it is interesting to note that Barnes and Kalostian (1) studied the flight habits of certain insects that infest stored raisins at Fresno, Calif. These workers found that the group *Laemophloeus* spp., which probably consisted for the most part of

*ferrugineus* (Steph.) (which has frequently been found associated with stored raisins), was most abundant in hot weather—July and August being the months of greatest activity. They reported a small amount of flight throughout the day when the temperature was above 65° F., with a period of increased activity for about two hours late in the afternoon, reaching a maximum from about 30 min. before sunset to 15 min. after.

#### Oviposition Rates of *Laemophloeus ferrugineus* at 90° F. and 65 to 75% Relative Humidity

No method was devised for determining exactly the number of eggs laid per day by a female of the rusty grain beetle, but an experiment was carried out that gave the total adult descendants of 20 individual females over a period of 23 days. Thus the approximate number of eggs laid per day could be estimated.

Twenty pairs of beetles were obtained while they were united in copulation. Ten pairs, one pair to each cage, were put into 3-oz. rearing cages. The other 10 copulating pairs were left undisturbed until they had finished mating and then the females, one to each cage, were put into similar cages. All of the cages had previously been filled with whole wheat.

By the above procedure it was certain that 20 mated females had been obtained, and that 10 of the cages each contained an isolated, inseminated female, while the other 10 each contained a male and female.

The cages were put into an incubator at 90° F. and 65 to 75% relative humidity and left for 46 days, when the adults present were counted. By choosing exactly 46 days the offspring of only the original female would be counted because the first of the third generation adults would not appear until about the 47th or 48th day under the conditions of the experiment. However, two possible sources of error remain: (1) the unknown mortality of the larvae, and (2) the unrecorded eggs that failed to hatch. Observations made during the course of other investigations lead to the belief that the mortality rate of uncrowded populations provided with suitable food is relatively low. It had also been noted that the percentage of eggs that hatch is quite high. Thus the progeny counts should give at least a good indication of the number of eggs laid per day by the individual females.

The results of this experiment are given in Table II. Five hundred and eighty-four eggs were laid by the 10 females living with males, or an average of 2.54 eggs per day per female, while the 10 isolated females laid 414 eggs or an average of 1.80 per female per day. This would indicate either that the females were stimulated to oviposition by periodic copulation, or that isolated females become infertile. Further experimentation would be necessary to establish final conclusion on this point. However, we may safely say that females of *Laemophloeus ferrugineus* can lay at least two or three eggs per day in whole grain at a temperature of 90° F. and a relative humidity of 65 to 75%.

TABLE II

TOTAL ADULT DESCENDANTS OF INDIVIDUAL *Laemophloeus ferrugineus* FEMALES  
FROM AN OVIPOSITION PERIOD OF 23 DAYS

Insect number	No. of beetles at end of experiment	No. of beetles at start of experiment	Increase	Average number of eggs laid per day
Pair 1	67	2	65	2.83
" 2	52	2	50	2.17
" 3	91	2	89	3.87
" 4	68	2	66	2.87
" 5	49	2	47	2.04
" 6	39	2	37	1.61
" 7	56	2	54	2.35
" 8	71	2	69	3.00
" 9	55	2	53	2.30
" 10	56	2	54	2.35
Average number of eggs laid per day per female				2.54
Female 1	37	1	36	1.57
" 2	57	1	56	2.43
" 3	30	1	29	1.26
" 4	43	1	42	1.83
" 5	61	1	60	2.61
" 6	63	1	62	2.69
" 7	42	1	41	1.78
" 8	37	1	36	1.57
" 9	22	1	21	0.91
" 10	32	1	31	1.35
Average number of eggs laid per day per female				1.80

### Temperature-Humidity Studies in the Development of *Laemophloeus ferrugineus* (Steph.)

#### EFFECT OF RELATIVE HUMIDITY ON THE LENGTH OF THE LARVAL AND PUPAL STAGES OF *Laemophloeus ferrugineus*

Desiccators were used as constant humidity chambers (9). Sulphuric acid solutions of definite strength prepared in the proportions shown in Table III were used to obtain the desired humidities (13).

TABLE III  
SULPHURIC ACID SOLUTIONS USED IN CONSTANT HUMIDITY CHAMBERS

Solution	Relative humidity, %	Amount of 95.5% sulphuric acid, cc.	Amount of distilled water, cc.	Specific gravity of solution
A	10	368	321	1.55
B	25	318	415	1.45
C	50	247	545	1.33
D	65	205	622	1.27
E	75	173	682	1.22
F	90	105	806	1.14

Solution A was prepared by adding 368 cc. of sulphuric acid to 321 cc. of distilled water. The acid was added very slowly to the water and the resulting solution allowed to stand until it cooled to room temperature. The specific gravity of the solution was then determined with a hydrometer, and either more water or more acid was added, if necessary, to bring the specific gravity of the solution to exactly 1.55. Each of the other solutions (B, C, D, E, and F) was prepared in a similar manner, using the amounts of acid and water given in Table III and then adjusting to the correct specific gravity.

Although these solutions did not provide the exact humidity desired at the different temperatures, they did give very close approximations because the variation in the percentage of sulphuric acid needed to give the same humidity at different temperatures is very slight if the temperature changes are not great.

An exploratory experiment was carried out to study the effect of relative humidity on development at temperatures of 80° and 90° F. The corners of a square piece of wire netting were bent down to form "legs" and the resulting wire "table," which fitted snugly into the desiccator, was placed so that its "legs" rested on the inner ledge of the desiccator. On this "table" was placed a wooden slide box, with glass slides in every second pair of grooves. Glass vials were stood between the rows of slides. Each box held 35 of these vials. A grain of wheat split longitudinally through the middle was put into each vial. Each of the 11 remaining desiccators was provided with a similarly prepared battery of rearing vials.

The desiccators were placed in the proper incubators running at constant temperatures of 80° and 90° F. After eight days, which allowed time for the moisture content of the wheat and the air in the desiccator to reach or approach equilibrium, eggs, one to each vial, were added to one of the batteries. On succeeding days vials in the remaining batteries were supplied with eggs. Each vial was provided with a cotton stopper, after being supplied with an egg.

The split kernel of wheat in each vial exposed to 90% relative humidity was covered with a dense growth of mold when the eggs were introduced, and this growth remained luxuriant during the period of the experiment.

The vials were examined each day until the eggs had hatched, or until it was definitely ascertained that they would not hatch. The battery was then left undisturbed until the pupae began to appear, when the vials were once again examined daily to note the date of emergence of adults. It will be noted in Table IV that in the battery kept at 75% relative humidity and 90° F. the adults had all emerged before the first examination was made. This was due to the fact that the interim between the hatching of the eggs and the emergence of the adult was shorter than had been anticipated. The average period from hatching to adult in this case was 20 days or less. In another experiment where 20 adults were reared under the same conditions of humidity and temperature but examined daily, this period averaged 20.5 days, so it is unlikely that the correct average in the first experiment would be much less than the 20 days recorded.

TABLE IV

EFFECT OF RELATIVE HUMIDITY AND TEMPERATURE ON THE RATE OF DEVELOPMENT  
OF *Laemophloeus ferrugineus* (STEPH.)

Tem- perature	R. H., %	No. of eggs not hatched	No. eggs hatched	No. of eggs hatched after exposure of:					No. larvae that died	No. adults emerged	Average develop- mental period, days
				1 Day	2 Days	3 Days	4 Days	5 Days			
80° F.	10	32	3	0	2	1	0	0	3	0	—
	25	6	29	7	6	8	7	1	29	0	—
	50	5	30	4	7	6	10	3	10	20	37.7
	65	7	28	3	8	6	7	4	1	27	35.9
	75	2	33	6	4	9	11	5	2	31	31.1
	90	1	34	8	2	5	13	5	2	32	35.2
90° F.	10	23	12	6	6	0	0	0	12	0	—
	25	22	13	1	8	3	1	0	13	0	—
	50	12	23	2	11	9	1	0	10	13	26.4
	65	8	27	7	8	12	0	0	0	27	23.1
	75	3	32	7	6	12	5	2	3	29	20 or less
	90	3	32	4	16	9	3	0	4	29	19.7

It may be seen from Table IV that no larvae survived at 10 and 25% relative humidities at the temperatures in question. When examining the hatching records it should be kept in mind that the eggs were laid under conditions of 75% relative humidity and a temperature of 80° F., and that their ages at the time of placing in the vials were not known. This means that eggs hatching in one day under the new conditions must have undergone most of their embryonic development before being exposed to these conditions. At 80° F. and 10% relative humidity only three eggs hatched; no eggs hatching after three days' exposure to the desiccating influence of 10% relative humidity. At 90° F. and 10% relative humidity 12 eggs hatched, but no eggs hatched after two days' exposure to this humidity.

Larval mortality is 100% at relative humidities of 10 and 25%, all the larvae dying in the first instar. At 50% relative humidity the mortality is 80% with most deaths occurring in the first instar. Humidities from 65 to 90% are favorable for survival and development of the larvae and pupae, as the mortality rate throughout this whole range was no greater than what might be considered the natural mortality rate.

From the standpoint of the total numbers of adults obtained from the eggs kept at humidities of 75 to 90%, the difference between the number emerged at 80° F. and 90° F. is so small as to be insignificant. But, on the other hand, if speed of development is considered, the same humidities at a temperature of 90° F. are much nearer to optimum conditions than at a temperature of 80° F.

The results also show that relative humidity affects the speed of larval development, the period of development decreasing with an increase in the relative humidity. To study this acceleration of development due to the

increase in relative humidity, another experiment was set up in which daily observations were made so as to determine the exact length of the different stadia. Three-tiered trays were used to hold the individual rearing cages in the constant humidity chambers. Each tray was taken from the chamber for a brief period each day in order to make the observations. Thus each set of rearing cages was exposed to room temperature and humidity for about 20 min. each day. One egg was added to each rearing cage and the larvae were fed on thin cross sections of wheat made through the germ region so as to include most of the germ. These sections were placed in the cages in the different humidity chambers eight days before the eggs were added, so that their moisture content would reach equilibrium with the air in the chambers.

Humidity chambers providing 25, 50, 65, 90, and 100% relative humidities were used in the experiment and all were kept at a constant temperature of 90° F. Figs. 28 to 32, inclusive, graphically depict part of the life history of *Laemophloeus ferrugineus* at the last five humidities mentioned above. In the 25% relative humidity chamber all the larvae died in the first instar. The first four horizontal sections of each graph represent the duration of the corresponding stadia, while the last horizontal portion of each graph shows the length of the pupal period. "X" indicates the emergence of the adult. The vertical lines represent time in days. The number to the left of each graph is the rearing cage number.

Data from these investigations are summarized in Table V which gives the arithmetic means for the lengths of the four larval stadia, and the pupal period in days. A study of these data shows that the acceleration of develop-

TABLE V  
EFFECT OF RELATIVE HUMIDITY ON THE RATE OF DEVELOPMENT  
OF *Laemophloeus ferrugineus* AT 90° F.

Developmental stages	Length of stadia in days at R.H. of:				
	50%	65%	75%	90%	100%
First instar	6.25	5.15	4.05	3.55	3.72
Second instar	5.83	4.25	2.75	2.89	2.50
Third instar	6.25	4.70	3.00	2.89	2.61
Fourth instar	9.50	7.90	7.45	7.49	6.83
Pupa	4.58	4.60	4.45	4.17	4.67
From hatching to adult	32.41	26.60	21.70	20.84	20.33

ment due to an increase in humidity took place during the feeding stages of the larvae, there being no speeding up of the rate of development during the pupal stage at any of the different humidities. The fact that the acceleration when the humidity is increased is relatively less in the fourth stadium than in the preceding stadia can be explained by the fact that the larva spends the last two or three days of the fourth stadium in the nonfeeding prepupal stage.

Most of the increase in the rate of development took place between relative humidities of 50 and 75%, there being no significant acceleration at humidities above 75%.

It is evident from the results of these humidity studies that infestations of *Laemophloeus ferrugineus* can develop in grain stored under relatively dry atmospheric conditions.

#### EFFECT OF TEMPERATURE ON THE INCUBATION PERIOD OF *Laemophloeus ferrugineus* EGG

Small squares of cardboard bearing several fine grooves made with a sharp knife were placed in a rearing cage that contained several adults. The following day the cardboards were removed to another container and examined daily to observe the time of hatching of the eggs that had been deposited in the grooves. The larvae present were removed at each observation. This method did not give the exact incubation period, as some of the eggs when first removed may have been almost 24 hr. old, while some may have been only a few minutes, but it did determine the approximate period.

This procedure was followed at temperatures of 80°, 90°, and 100° F.

Of a total of 37 eggs kept at 80° F., 22 hatched in 4 days, 14 hatched in 5 days, and one did not hatch; of 83 eggs at 90° F., 60 hatched in 3 days, 20 hatched in 4 days, and 3 did not hatch; while at 100° F. out of a total of 32 eggs, 11 hatched in 2 days, 19 hatched in 3 days, and 2 failed to hatch. These results show that for each rise of 10 degrees in temperature the incubation period was shortened by about one day. At a relative humidity of 75%, eggs at 100° F. hatched in 2 to 3 days, at 90° F. in 3 to 4 days, and at 80° F. in 4 to 5 days.

#### EFFECT OF TEMPERATURE ON THE LENGTH OF THE LARVAL AND PUPAL STAGES OF *Laemophloeus ferrugineus* AT A CONSTANT RELATIVE HUMIDITY OF 75%

Five different constant humidity chambers were prepared so that each provided a relative humidity of 75%. Each chamber was equipped with a three-tiered tray on which were placed 20 individual rearing cages. A thick

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*Graphs showing the effect of different humidities upon the developmental rate of larvae and pupae of *Laemophloeus ferrugineus* (Steph.). (The horizontal bars at successive elevations show the duration in days of the first, second, third, and fourth stadia, and the pupal stage, respectively.) R.H. = Relative humidity.*

FIG. 28. Developmental graphs for *Laemophloeus ferrugineus* at a relative humidity of 50%.

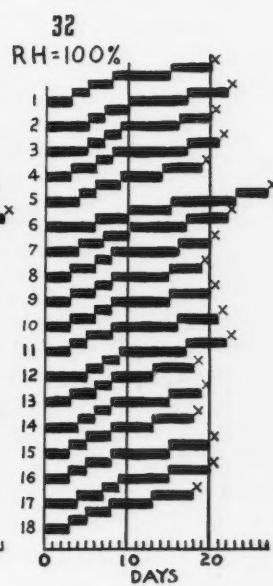
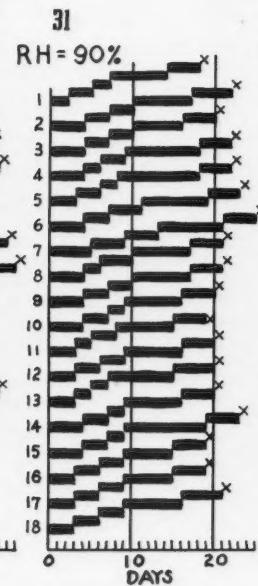
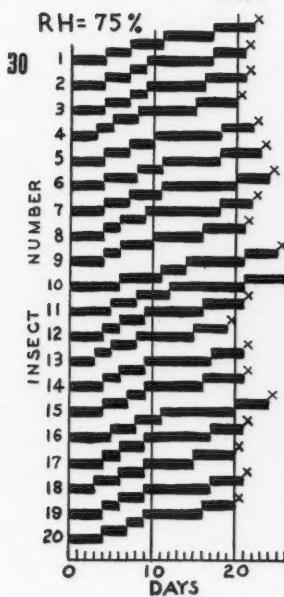
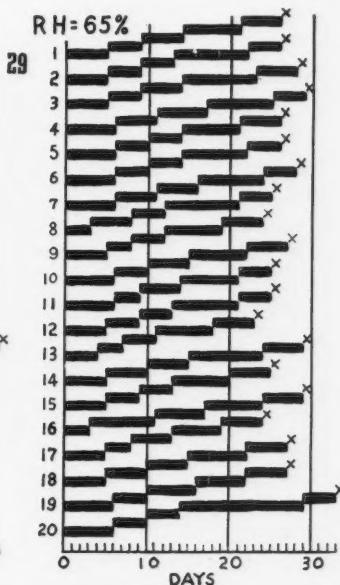
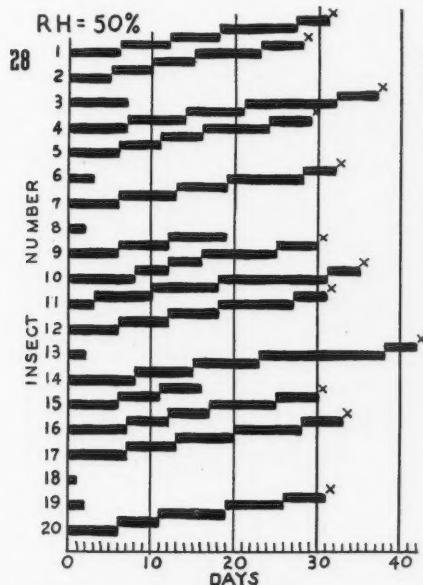
FIG. 29. Developmental graphs for *Laemophloeus ferrugineus* at a relative humidity of 65%.

FIG. 30. Developmental graphs for *Laemophloeus ferrugineus* at a relative humidity of 75%.

FIG. 31. Developmental graphs for *Laemophloeus ferrugineus* at a relative humidity of 90%.

FIG. 32. Developmental graphs for *Laemophloeus ferrugineus* at a relative humidity of 100%.

cross section through the germ region of a wheat kernel was used as food in each of the rearing cages. One egg was placed into each cage and daily inspections were made with a binocular microscope until all the adults had



emerged. The discovery and removal of the cast-off exuviae from the container was the evidence relied upon in tabulating the time of molting. Each of the humidity chambers was kept in incubators at different temperatures so that records of the rate of development at temperatures 70°, 80°, 90°, 100°, and 110° F. were obtained. Figs. 33 to 36, inclusive, graphically depict part of the life history of *Laemophloeus ferrugineus* at the first four temperatures mentioned above. At 110° F. the eggs either failed to hatch or the larvae died immediately after eclosion. The first four horizontal sections of each graph represent the duration of the four larval stadia, while the last horizontal section of each graph shows the length of the pupal period. "X" indicates the emergence of the adult. The vertical lines represent time in days, and the number to the left of each graph is the rearing cage number.

TABLE VI

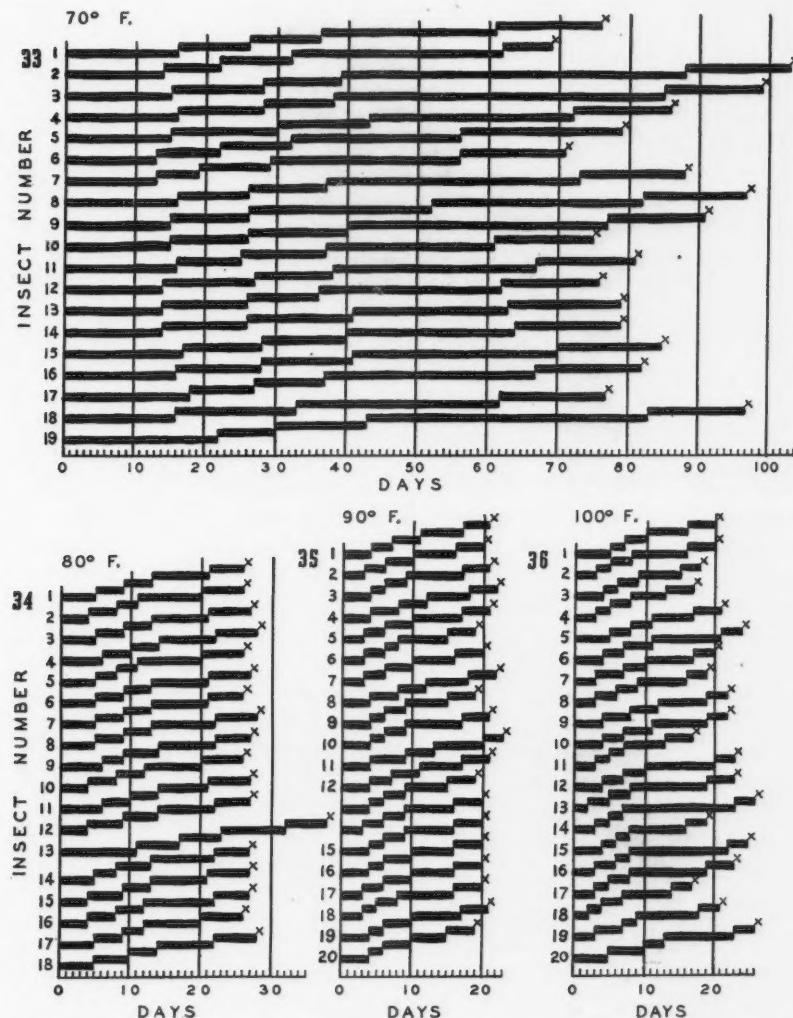
EFFECT OF TEMPERATURE ON THE RATE OF DEVELOPMENT OF *Laemophloeus ferrugineus* AT 75% RELATIVE HUMIDITY

Developmental stages	Length of period in days			
	70° F.	80° F.	90° F.	100° F.
First instar	15.5	5.2	3.7	3.5
Second instar	10.6	4.4	2.1	2.8
Third instar	12.5	4.4	3.6	2.9
Fourth instar	30.9	8.3	6.7	8.6
Pupa	14.7	5.7	3.9	3.4
Developmental period from hatching of egg to adult	64.2	27.4	20.5	21.0

Data from these investigations are summarized in Table VI, which gives the arithmetic means for the lengths of the four larval stadia, and the pupal period in days. A study of these data shows that an acceleration in the rate of development occurred for each increase in temperature. An increase in temperature from 70° to 80° shortened the time from hatching of the egg to the emergence of the imago by 57 days, while an increase from 80° to 90° F. shortened this developmental period by seven days. An increase from 90° to 100° F. did not shorten the average length of this developmental period. The minimum developmental periods were 69, 26, 19, and 17 days at 70°, 80°, 90°, and 100° F., respectively, while the maximum periods for the same temperatures were 103, 38, 23, and 26 days, respectively. On the average it took more than four times as long for the rusty grain beetle to develop through the larval and pupal stages at 70° F. than it did at 90° F. Most of this great difference in rate of development occurred between 70° and 80° F.

The fact that development is not as uniform at 100° F. as at 90° F. may indicate that the optimum temperature has been passed when 100° F. is

reached. This would mean that for the rusty grain beetle the optimum temperature for speed of development at 75% relative humidity is somewhere near 90° F.



Graphs showing the effect of temperature upon the larval and pupal development rate at a constant relative humidity of 75%. (The horizontal bars at successive elevations show the duration in days of the first, second, third, and fourth stadia, and the pupal stage, respectively.)

FIG. 33. Development graphs for *Laemophloeus ferrugineus* at a temperature of 70° F.

FIG. 34. Development graphs for *Laemophloeus ferrugineus* at a temperature of 80° F.

FIG. 35. Development graphs for *Laemophloeus ferrugineus* at a temperature of 90° F.

FIG. 36. Development graphs for *Laemophloeus ferrugineus* at a temperature of 100° F.

An interesting difference in the length of the various stadia is revealed in Figs. 33 to 36, inclusive, especially when the duration of the fourth larval instar stage at the four different temperatures is compared with the periods of the other instars at the same temperatures. The retarded speed of development of the fourth instar at 100° F., after extremely rapid development in the first three instars (see numbers 13, 14, 16, and 17; Fig. 36) suggests that at this high temperature the molting processes are so strongly stimulated that molting occurs ahead of other ontogenetic developments, and that the last molt is delayed in order that these other changes be allowed to catch up. It appears that in the process the total time required is actually as great or greater than that of those individuals that developed more slowly in the earlier instars. A possible explanation of this retarded development of the fourth instar-larvae reared at 100° F. is contained in a report by Nelson and Palmer (8). They found that larvae of the flour beetle, *Tribolium confusum* Duval, must eat sufficient food to bring their phosphorus content up to a certain level before pupation would occur. It might be possible, therefore, that the very rapidly developing larvae of *Laemophloeus ferrugineus* did not assimilate during the first three stadia and the first two or three days of the fourth stadium enough phosphorus to permit pupation, and therefore longer feeding periods by the fourth instars were necessary to make up this deficiency.

It has already been mentioned that first instar larvae were not able to survive at a temperature of 110° F. and relative humidity of 75%. Since *Laemophloeus ferrugineus* has been recovered from heating grain at temperatures of at least 110° F. it was decided to determine what effect this temperature would have on the adults and older larvae. One hundred adult beetles, kept at 110° F. in an incubator in which a large evaporating dish filled with water was kept just below the electric fan at the top of the incubator, lived a normal existence for about one month until the evaporating dish was allowed to become empty. A few days later all the beetles were dead. Third and fourth instar larvae kept in the same incubator at the same temperature and high humidity were observed to remain alive for several days.

These observations suggest that adults of *Laemophloeus ferrugineus* at high relative humidities can tolerate higher temperatures than the first larval instars, and that all stages can live at high temperatures when the humidity is high.

#### Longevity of *Laemophloeus ferrugineus* Adults

On May 1, 1945, a single fourth instar larva was placed in each one of 100 small-sized rearing cages. The larvae were provided with cracked wheat as food, and kept at 90° F. and 65 to 75% relative humidity. On May 12, the cages were examined and an adult beetle was found in each. The 100 beetles were obtained in this manner so as to be sure that all the insects used were not more than a day or two old at the start of the experiment. This would not have been the case if beetles had been chosen at random from any of the stock cultures.

The cages were inspected once each month and a record kept of the dead beetles found. Table VII lists the results of these inspections and gives the total percentage dead at the end of each month.

TABLE VII

LONGEVITY OF *Laemophloeus ferrugineus* ADULTS FED ON CRACKED WHEAT  
AND MAINTAINED AT 90° F. AND 65 TO 75% RELATIVE HUMIDITY

Inspection date	Number of dead beetles	Percentage of total insects dead
May 12, 1945	0	0
June 12, "	0	0
July 12, "	2	2
Aug. 12, "	3	5
Sept. 12, "	4	9
Oct. 12, "	5	14
Nov. 12, "	13	27
Dec. 12, "	13	40
Jan. 12, 1946	37	77
Feb. 12, "	8	85
Mar. 12, "	11	96
Apr. 12, "	1	97

It will be seen from this table that at the end of the 11th month 97% of the beetles were dead, while at the end of the seventh month only 40% were dead. Thirty-seven per cent of the insects died in the eighth month of their adult life. We may conclude therefore, that at 90° F. and 65 to 75% relative humidity, and with cracked wheat as food, the adults of *Laemophloeus ferrugineus* live, on the average, from six to nine months, and a few may live as long as one year. This life span is somewhat longer than might be expected at a temperature as high as 90° F. and it almost certainly would be even longer at lower temperatures, where metabolic activities would be correspondingly reduced.

The longevity of adult beetles deprived of all food was also investigated. A single beetle was placed in each of 56 individual cages. Each cage had been thoroughly cleaned prior to the introduction of the imago. Table VIII gives the results of daily inspections of each cage to discover when its occupant died. The table shows that although one starved adult beetle lived as long as 17 days, more than one-half of the beetles were dead at the end of eight days. Seventy-one per cent of the beetles died between the 7th and 11th days inclusive.

#### The Suitability of Whole Wheat as Larval Food for *Laemophloeus ferrugineus* (Steph.)

A quantity of wheat, examined a kernel at a time to make certain that no damaged grains were included, was prepared. One-half of these undamaged kernels was soaked in water for five minutes and then removed and allowed

to dry by exposure to the air in the laboratory. Later five kernels of the water-soaked wheat were put into each of 20 rearing cages. Into each of another 20 cages were placed five kernels from the unmoistened half of the

TABLE VIII

LONGEVITY OF STARVED *Laemophloeus ferrugineus* ADULTS AT 90° F.  
AND 65 TO 75% RELATIVE HUMIDITY

Inspection date	Number of dead beetles	Percentage of total insects dead
Feb. 8 (Expt. started)	0	0
" 9	0	0
" 10	0	0
" 11	2	3.6
" 12	1	5.4
" 13	4	12.5
Feb. 14	4	19.6
" 15	7	32.1
" 16	13	55.4
" 17	10	73.2
" 18	5	82.1
" 19	5	91.1
Feb. 20	2	94.6
" 21	1	96.4
" 22	0	96.4
" 23	1	98.2
" 24	0	98.2
" 25	1	100.0

undamaged wheat. All the cages were then put into an incubator running at 80° F. and 75% relative humidity, and left for a few days, in order that the moisture content of the grain might reach equilibrium with that of the air. Then one egg was placed in each cage. In the few instances in which the egg did not hatch, a new egg was added. The cages were inspected daily until all the eggs had hatched; then they were left undisturbed for 15 days when the kernels were examined for insect damage.

This examination showed that all of the larvae except one had developed in a burrow in the germ region of the wheat kernel. The larval burrows were the result of the excavations brought about as the larvae fed on the wheat embryos. One larva had developed in the endosperm region in close proximity to the germ, a little of the germ being also consumed. There was no significant difference in susceptibility to insect attack between the water-soaked wheat and the untreated wheat.

The high rate of survival in the sound whole wheat does not agree with many reports in the literature that state that *Laemophloeus ferrugineus* is a

secondary pest able to attack only grain that is already damaged by primary pests, such as the weevils and grain borers, or some other agent. The question of how the larvae actually gain access to the germ region then arose. Previously it had been noticed, while making dissections of wheat kernels from cultures of *Laemophloeus ferrugineus* being studied in the course of other investigations, that a certain proportion of wheat remained undamaged regardless of the beetle population or the duration of the infestations. Since five kernels were used in each of the rearing cages in the above experiment, each larva had to penetrate only one of the five to successfully complete its development. Thus there might have been kernels in each cage that could have withstood attack by the newly hatched larva. With this possibility in mind various samples of wheat were examined microscopically and it was discovered that very small breaks were discernible on many of the kernels, especially in the germ region.

In almost 50% of the "undamaged kernels" examined small breaks were found in the seed coats covering the germ region. Through these lesions the root cap of the radicle could often be seen. The Henry wheat used in this examination was obtained from the Wisconsin Experiment Station and had received more careful handling during harvesting and threshing than most farm grains receive. Furthermore, this grain had been stored under ideal conditions and had not been subjected to rough handling. Therefore, this sample could not be designated as damaged grain in the ordinary sense, although it had almost 50% of the kernels showing microscopic breaks in the bran layers. In order to determine whether *Laemophloeus ferrugineus* larvae could successfully attack intact kernels showing no lesions under microscopic examination, 278 whole undamaged kernels of Henry wheat were selected and examined carefully under the medium power of a binocular microscope. The embryo end of the wheat was examined very carefully. Any kernels showing the slightest evidence of a break in the bran layers were separated from those showing none. Twenty rearing cages were prepared and five kernels of wheat with broken bran layers were added to each cage. Twenty cages containing five kernels of wheat with no breaks in their bran layers were also prepared. Three eggs of the rusty grain beetle were placed in each cage. The cages were then put into the incubator and kept at 90° F. and 75% relative humidity. Nineteen days later the cages were removed and the kernels examined for insect damage. The results are recorded in Table IX. They show conclusively that the first instar larva of *Laemophloeus ferrugineus* is unable to attack whole wheat that has no breaks in the bran layers. The lone kernel damaged out of a total of 100 probably had a slight break in the germ covering that was missed during the microscopic examination. At least it cannot be assumed from this single exception that the larva had eaten its way through the bran layers. This table also shows that whole "undamaged" wheat that has small breaks in the layers over the germ region is easily attacked by first instar larvae. A total of 3 larvae, 33 pupae, and 1 adult was found in the cages containing the wheat with breaks in the bran layers.

TABLE IX

COMPARISON OF *Laemophloeus ferrugineus* DAMAGE TO WHEAT KERNELS WITH BROKEN AND UNBROKEN BRAN LAYERS OVER THE GERM REGION

Kernels with breaks in bran layer			Kernels with no apparent break in bran layer		
Cage No.	No. of kernels showing insect damage	No. of kernels showing no insect damage	Cage No.	No. of kernels showing insect damage	No. of kernels showing no insect damage
1	2	3	21	0	5
2	2	3	22	0	5
3	2	3	23	0	5
4	3	2	24	0	5
5	2	3	25	0	5
6	1	4	26	0	5
7	2	3	27	0	5
8	2	3	28	0	5
9	3	2	29	0	5
10	2	3	30	0	5
11	2	3	31	0	5
12	2	3	32	0	5
13	1	4	33	0	5
14	3	2	34	0	5
15	1	4	35	0	5
16	2	3	36	0	5
17	2	3	37	0	5
18	2	3	38	0	5
19	1	4	39	1	4
20	1	4	40	0	5

#### Suitability of the Different Parts of Wheat as Larval Food

Four experiments running concurrently under the same conditions of temperature and humidity (80° F. and 75% relative humidity) were conducted, the only variable being the food. The four lots A, B, C, and D, consisting of 20 rearing cages each, were provided with white flour, bran, a cross section of wheat containing wheat germ, and a cross section of wheat without germ, respectively. The lengths of the larval and pupal periods were recorded, and the larval periods are given in Table X.

A summary of the data of Table X is shown in Table XI. A glance at this table shows that wheat germ is by far the best larval food, whether percentage survival or rate of development is considered. Bran ranks second, with a mortality rate of only 11%, but the length of the larval period is more than doubled. White flour is next with a high mortality rate and a still longer larval period. Wheat with the germ end removed, although it contains the bran portion as well as the endosperm, is almost totally unsuitable as larval food. This indicates that the major reason for the high mortality in the latter case is the larva's inability to obtain nourishment because of the hardness of this portion of the wheat kernel.

The length of the pupal stage was the same for all four foods, the period averaging six days.

TABLE X

## A COMPARISON OF THE DIFFERENT PARTS OF WHEAT AS LARVAL FOOD

Group A (white flour)		Group B (bran)		Group C (wheat germ)		Group D (wheat without germ)	
Rearing cage no.	Length of larval stage in days	Rearing cage no.	Length of larval stage in days	Rearing cage no.	Length of larval stage in days	Rearing cage no.	Length of larval stage in days
1	Egg didn't hatch	21	Died, 1st instar	41	22	61	38
2	66	22	65	42	20	62	34
3	Died, 1st instar	23	33	43	Killed	63	Died, 1st instar
4	Egg didn't hatch	24	Egg didn't hatch	44	21	64	" " "
5	Died, 1st instar	25	38	45	20	65	" " "
6	61	26	42	46	21	66	" " "
7	Died, 1st instar	27	36	47	22	67	" " "
8	" 2nd "	28	60	48	20	68	" " "
9	" " "	29	51	49	21	69	" " "
10	Died, 1st instar	30	67	50	21	70	" " "
11	51	31	60	51	22	71	Died, 1st instar
12	54	32	Egg didn't hatch	52	22	72	" " "
13	58	33	79	53	Died, 1st instar	73	" " "
14	Died, 1st instar	34	66	54	20	74	" " "
15	" 2nd "	35	Died, 1st instar	55	21	75	" " "
16	Died, 3rd instar	36	46	56	22	76	" " "
17	53	37	48	57	32	77	" " "
18	Died, 1st instar	38	65	58	22	78	" " "
19	49	39	47	59	21	79	" 2nd "
20	Died, 1st instar	40	60	60	22	80	" " "

TABLE XI

COMPARISON OF DIFFERENT PARTS OF WHEAT AS FOOD FOR  
*Laemophloeus ferrugineus* LARVAE

Food provided	Mortality, %	Average length of larval stage in days
White flour	61	56
Bran	11	50
Wheat without germ	90	36
Wheat with germ	5	21.8

Susceptibility of Grain Kernels and Oil Seeds to  
Damage by *Laemophloeus ferrugineus*

Ten kernels each of Henry wheat, Imperial rye, Wisconsin Number 38 barley, Vicland oats, soybeans, a single hybrid dent corn, Redson flax, sunflower, and Zenith rice, were placed into each of 10 large-size metal rearing cages. The 90 seeds per cage did not completely cover the floor of the cage and as a result each seed was more or less isolated.

Ten unsexed beetles were added to each cage and the cages sealed with Scotch tape, treated with Tree Tanglefoot to prevent contamination, and placed in an incubator running at 90° F. and a relative humidity of 60 to 70%. The kernels in six of the cages were examined and the damaged kernels and insects present counted, 37 days after the start of the experiment, and those in the remaining cages after 71 days. The results are given in Table XII.

TABLE XII

SUSCEPTIBILITY OF VARIOUS GRAINS AND SEEDS TO DAMAGE BY *Laemophloeus ferrugineus* AT 90° F. AND 60 TO 70% RELATIVE HUMIDITY

Rearing cage number	Incubation period in days	Number of kernels damaged								
		Imperial rye	Henry wheat	Dent corn	Zenith rice	Vicland oats	Wis. No. 38 barley	Sun-flower	Flax	Soy-beans
1	37	6	1	0	0	0	0	0	0	0
2	37	7	2	2	0	0	0	0	0	0
3	37	7	2	0	1	0	0	0	0	0
4	37	6	4	2	0	0	0	0	0	0
5	37	4	0	0	0	0	0	0	0	0
6	37	7	4	2	0	0	0	0	0	0
7	71	6	2	1	0	0	0	0	0	0
8	71	8	4	0	0	0	0	0	0	0
9	71	5	2	1	0	0	0	0	0	0
10	71	6	2	1	0	0	0	0	0	0
Totals		62	23	9	1	0	0	0	0	0

A glance at this table shows that rye is the most susceptible to attack by *Laemophloeus ferrugineus* of any of the grains in this experiment. Wheat, corn, and rice were decreasingly susceptible, in the order named. Barley, oats, sunflower, flax, and soybeans were not damaged at all under the conditions of this experiment.

The high mortality rate among the adults, and the close correlation between the number of damaged seeds and the increase in the number of insects, as shown in Table XIII, indicate that most of the injury to the damaged kernels was caused by larvae rather than adults.

The type of damage caused by larvae feeding on kernels of corn, wheat, and rice are illustrated in Figs. 37, 39, 40, and 41.

#### The Comparative Suitability of Damaged and Undamaged Grains and Oil Seeds for the Development of *Laemophloeus ferrugineus*

For this experiment the damaged grains and seeds were obtained by running them through a small hand corn-grinder. The grinder was adjusted so that the resulting meal was very coarse. The whole grains and seeds were considered as undamaged because they were obtained from grade one lots in first class condition.

PLATE I



37



39



40



41

FIG. 37. Typical damage by *Laemophloeus ferrugineus* larvae to the germ of Dent corn.

FIG. 38. Eggs of *Laemophloeus ferrugineus*.

FIG. 39. Adult of *Laemophloeus ferrugineus* emerging from a kernel of hybrid Dent corn.

FIG. 40. Wheat kernels degenerated by *Laemophloeus ferrugineus* larvae.

FIG. 41. Rye kernels degenerated by *Laemophloeus ferrugineus* larvae.

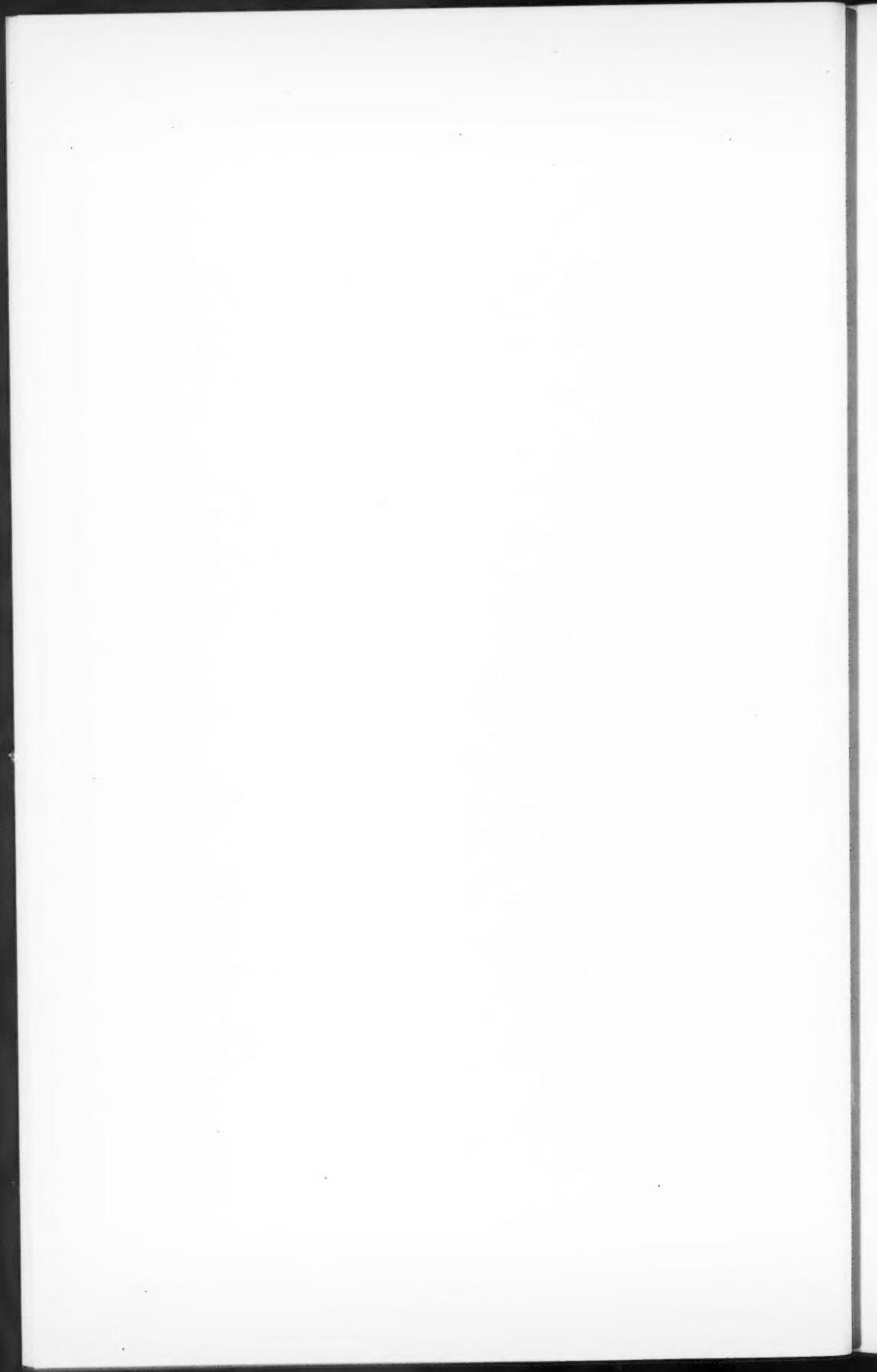


TABLE XIII

POPULATION INCREASES OF *Laemophloeus ferrugineus* AND NUMBERS OF DAMAGED KERNELS IN A SERIES OF REARING CAGES

Rearing cage number	Dead adults	Live adults	Larvae	Pupae	Total population increase	Total damaged kernels
1	10	6	0	0	6	7
2	14	6	4	0	14	11
3	12	7	1	0	10	10
4	9	8	1	1	9	12
5	7	7	0	0	4	4
6	5	6	6	2	9	13

The large-size rearing cages were used. They were filled almost to the top and then heated to a temperature of 130° F. for 12 hours, after which they were allowed to cool. Twenty unsexed beetles were added to each cage, the lid sealed with Scotch tape, and the top treated with Tree Tanglefoot. The Scotch tape prevented book-lice, mites, or parasites from gaining entrance to the cages around the edges of the lids. The Tanglefoot kept any other pests from entering through the bolting-cloth-covered opening in the lid. The cages were kept for 47 days at a temperature of 90° F. and a relative humidity of 65 to 75%. Henry wheat, Zenith rice, Imperial rye, single hybrid Dent corn, Vicland oats, Redson flax, Wisconsin oats No. 219-12, soybeans, Blackhawk wheat, sunflower, and Wisconsin barbless barley were the foods studied. Two replicates of each food and each treatment were used.

A duplicate experiment was carried out exactly as above, with the exception that the foods were not heated prior to the introduction of the beetles, but instead were moistened with a few drops of water.

Total counts of the adults present in each cage were taken at the end of 47 days and the data obtained are given in Table XIV.

The total increases of adults on the different foods in all replicates are given in Table XV. However, it must be kept in mind while examining Tables XIV and XV that only adults were counted, and the fact that no increase is shown for some of the foods does not mean that *Laemophloeus ferrugineus* will not develop on them. For example, flax seed shows no increase in the number of adults, but many young larvae were observed in the damaged seed when it was being screened for adults. It should also be mentioned that in the case of the flax seed it was impossible, because of the similar color of the flax meal particles and the rusty grain beetles, to recover and count the dead beetles. The number of dead beetles listed for flax seed in Table XIV was derived by subtracting the number of live beetles recovered from the original number placed in each cage. The live beetle counts should be reasonably accurate, as they were secured by screening the foods, a small quantity at a time, into a

TABLE XIV

POPULATION INCREASES OF *Laemophloeus ferrugineus* IN VARIOUS WHOLE AND DAMAGED FOODS

Food	Condition of food	First run (heated)			Second run (moistened)		
		Beetles		Increase	Beetles		Increase
		Alive	Dead		Alive	Dead	
Henry wheat	Whole	236	15	231	260	17	257
	"	182	32	194	328	13	321
	Damaged	37	7	24	213	12	205
	"	63	6	49	241	9	230
Blackhawk wheat	Whole	52	14	46	216	13	209
	"	101	16	97	263	10	253
	Damaged	73	4	57	90	2	72
	"	48	11	39	117	1	98
Imperial rye	Whole	100	14	94	502	15	497
	"	190	15	185	248	11	239
	Damaged	45	2	29	247	8	235
	"	70	8	58	198	13	190
Vicland oats	Whole	1	19	0	6	14	0
	"	4	18	2	3	17	0
	Damaged	28	11	19	28	9	17
	"	45	4	29	171	6	157
Wisconsin oats 219-12	Whole	13	11	4	9	12	1
	"	0	20	0	21	6	7
	Damaged	35	4	19	36	2	18
	"	76	3	59	200	8	188
Wisconsin No. 38 barley	Whole	6	21	7	15	13	8
	"	18	14	12	4	16	0
	Damaged	81	10	71	81	14	75
	"	88	8	76	143	11	134
Zenith rice	Whole	51	26	57	82	10	72
	"	38	34	52	73	14	67
	Damaged	63	33	76	129	13	122
	"	170	22	172	39	6	25
Corn	Whole	12	18	10	17	9	6
	"	16	9	5	21	7	8
	Damaged	26	17	23	18	12	10
	"	37	14	31	37	14	31
Sunflower	Whole	7	13	0	10	15	5
	"	1	19	0	4	16	0
	Damaged	10	12	2	6	14	0
	"	16	10	6	7	13	0
Flax	Whole	0	20	0	4	16	0
	"	2	18	0	5	15	0
	Damaged	3	17	0	3	17	0
	"	1	19	0	2	18	0
Soybeans	Whole	0	20	0	0	20	0
	"	1	19	0	2	18	0
	Damaged	19	5	4	15	5	0
	"	20	7	7	14	8	2

large white evaporating dish. The live beetles were easily detected moving over the white surface of the dish and could be counted as they were sucked up into an aspirator.

TABLE XV

SUMMARY OF TOTAL INCREASES OF ADULT BEETLES FOR THE FOUR REPLICATES REPORTED IN TABLE XIV

Food	Insect increase	
	Whole food	Damaged food
Henry wheat	1003	508
Blackhawk wheat	605	266
Imperial rye	1015	512
Vicland oats	2	222
Oats 219-12	12	284
Wisconsin No. 38 barley	27	356
Zenith rice	248	395
Corn	29	95
Sunflower	5	8
Flax	0	0
Soybeans	0	14

It is quite certain that whole wheat or rye is more conducive to rapid increase in numbers of rusty grain beetles than are damaged kernels of the same grains. At first thought the reason for this seems obscure, but at least two factors may be responsible. It has been shown elsewhere in this report that larval development is much more rapid when the insect is feeding on germ than when it is feeding on endosperm. In the process of grinding, the germ portions become broken and dispersed so that the feeding larva, instead of finding enough germ at one location to complete its development, would be forced to move from place to place if only wheat germ were to be eaten. It is quite probable, therefore, that in the damaged grain a higher proportion of endosperm is eaten per larva than in the undamaged whole grain. This would result in a retardation in the rate of population increase. The second factor, namely the effect of cannibalism, may be of more importance than the suggestion just made. It has been observed on many occasions that the prepupae and pupae are very vulnerable to attack by larvae. In whole grain habitats the openings to the larval burrows usually are sealed with debris held together by silken strands just before the larvae enter the prepupal stage. This "debris plug" may be of importance in keeping female adults from ovipositing in the burrows, as well as in preventing migrating larvae from entering. It is not unreasonable to assume that cases of cannibalism might be much more numerous in damaged grain, where almost every prepupa and pupa is without the protection provided by a sealed larval burrow, than they are in undamaged grain.

Rye, Henry wheat, and Blackhawk wheat were the most satisfactory of the foods tested for the development of *Laemophloeus ferrugineus*. It has been shown elsewhere that rye is much more vulnerable to attack by larvae

than wheat, and this experiment shows that the nutritive properties of rye are just as suitable for the insect as those of wheat. Therefore, in the case of wheat or rye, *Laemophloeus ferrugineus* cannot be considered as a secondary pest, depending on initial damage to the grain by other insects. However, in the case of oats, barley, corn, sunflower, flax, and soybeans it appears that the insect should be classed as a secondary pest. With the latter foods the populations increased more rapidly in the damaged grains, although in no case was the increase as great as that in wheat or rye. In fact, the whole kernels and seeds of this list were very resistant to insect attack and the very small increases shown in these whole foods may have been due to the presence of a few damaged kernels or seeds that are always present in any sample of grain or seeds. Where rice was used as food the results were about the same for the whole as for the damaged kernels, with the latter giving somewhat more rapid population build-ups.

Therefore we may conclude that under certain conditions *Laemophloeus ferrugineus* is not a secondary pest of rye or wheat, and possibly of rice, but that it may be considered a secondary pest of oats, barley, sunflower, soybeans, corn, and flax, when we define a secondary pest as one that must follow in the wake of some other insect pest if it is to be successful.

#### The Comparative Suitability of Weevil-infested and Undamaged Grain for the Establishment of Infestations of *Laemophloeus ferrugineus*

Ten rusty grain beetles were placed in each of four half-pint jars of wheat heavily infested with granary weevils, *Sitophilus granarius* (Linn.), and the same number of beetles were placed in each of four similar jars containing whole undamaged wheat. All eight jars were kept in an incubator at 90° F. and 65 to 75% relative humidity for 41 days, after which counts of adults were made. The results of these counts are given in Table XVI.

These results show that under the conditions of this experiment weevil-infested grain was no more favorable for the establishment of *Laemophloeus ferrugineus* than whole uninfested grain. However, it is interesting to note

TABLE XVI  
NUMBER OF *Laemophloeus ferrugineus* ADULTS PER JAR

Jar No.	No. of <i>Laemophloeus ferrugineus</i> adults	No. of weevils	Condition of grain at start of experiment
1	215	430	Weevil-infested
2	86	278	" "
3	126	289	" "
4	128	311	" "
5	78	0	Undamaged
6	201	0	"
7	182	0	"
8	245	0	"

the apparent lack of competition between the two species, in spite of the large numbers of weevils present and the small size of the jars. This suggests that under low humidity conditions the presence of weevils may actually be an advantage to the rusty grain beetle, as has often been suggested in the literature. However, there would be no advantage in the case of wheat with a high moisture content.

### Effect of Molds on Larval Development

Early experiments during the course of this work showed practically 100% mortality when larvae were supplied with cross sections of wheat that contained no wheat germ as the only source of food. Yet when supplied with bran or white flour the mortality rates were only 11% and 61%, respectively.

An experiment was set up to determine whether the food material contained in wheat that lacked the germ portion could be made available to larvae by the presence of molds. For this purpose three sets of 20 thick cross sections were prepared. Each section was examined under the binocular microscope to ensure that none of the wheat germ remained. The first set was left as an untreated control. The second set was soaked for 15 minutes in a solution of taka-diastase, made by adding 0.5 cc. of water to an amount of commercial taka-diastase that thinly covered the surface of a 10¢ coin. The third set was placed in an incubator at a high humidity until mold growth became luxuriant.

The sections from each set were then placed, one to each cage, into the individual rearing cages, which were then put in an incubator running at 80° F. and 75% relative humidity. After allowing one week for the grain moisture to reach equilibrium with the moisture of the air, an egg was placed in each cage and the period from the hatching of the egg to the emergence of the imago was recorded. The results are given in Table XVII. The 10% survival in the untreated control is in marked contrast with the 90% survival in the other two sets of cages.

The enzyme diastase acts on raw starch, dissolving it, and splitting it through the dextrin stage into maltose. However, not all the starch is converted entirely into maltose, a portion of it being left as dextrin. The maltose is usually hydrolyzed to glucose by the maltase present in the enzyme mixture. Thus in the case of the diastase-treated sections at least two changes resulted. First, a large proportion of the starch present in the sections was converted into forms that perhaps could be more readily assimilated by the larvae and, second, the sections were made considerably softer in texture. Which of these two changes was mainly responsible for the great decrease in mortality is not known.

However, this experiment showed that the survival of larvae fed on moldy sections was approximately the same as that of those fed on diastase-treated sections. It is well known that diastase is of wide occurrence among molds.

TABLE XVII

DEVELOPMENT OF *Laemophloeus ferrugineus* LARVAE ON THICK CROSS  
SECTIONS OF WHEAT CONTAINING NO GERM

Untreated sections		Taka-diestase sections		Moldy sections	
Cage No.	Period from hatching to adult	Cage No.	Period from hatching to adult, days	Cage No.	Period from hatching to adult, days
1	Died, 1st inst.	21	44	41	Died, 1st instar
2	" " "	22	46	42	52
3	" " "	23	39	43	32
4	" " "	24	44	44	32
5	44 days	25	39	45	38
6	Died, 1st inst.	26	38	46	34
7	" " "	27	39	47	30
8	" " "	28	44	48	34
9	40 days	29	36	49	32
10	Died, 2nd inst.	30	37	50	37
11	Died, 2nd inst.	31	40	51	Egg not hatched
12	" 1st "	32	Egg not hatched Died	52	36
13	" " "	33		53	35
14	" " "	34		54	49
15	" " "	35		55	35
16	" " "	36	42	56	45
17	" " "	37	43	57	44
18	" " "	38	43	58	36
19	" " "	39	43	59	42
20	" " "	40	39	60	Died, 1st instar

*Summary*

Treatment	Mortality rate, %	Period average (hatching to adult), days
Untreated control	90	42.0
Taka-diestase treated	10	40.6
Moldy	10	37.8

Whether or not the similarity of the survival rates obtained was due to the formation of diestase by the molds present was not established, but certainly the possibility of this being the case is a reasonable one.

This experiment definitely proves that the growth of molds upon a substratum of wheat endosperm converts the latter into more suitable larval food. From this it may be concluded that the presence of molds in stored wheat greatly increases the total amount of food suitable for the developing larvae by making the starch portion of the wheat more readily available as larval food.

Every larva that survived in both the moldy and diastase-treated wheat burrowed into the endosperm where it hollowed out a tiny cell in which it developed. Although both sides of the cross sections exposed large surface of the endosperm, many of the adults were held prisoners in their burrows, the openings being too small for the adults to escape.

It is of interest to note, while discussing the effect of molds upon larval development, that in order to obtain eggs in sufficient numbers for the various experiments carried out in the course of these investigations, it was necessary to keep the adults in wheat with a moisture content sufficiently high to encourage mold growth. Whether the high humidity alone, or the presence of molds as well, was a contributing factor causing this increased oviposition was not ascertained.

Larvae, adults, and eggs have frequently been found in abundance in cultures of wheat with such a high moisture content that the grain had been converted into a dark colored spongy mass by the action of the microorganisms present.

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## STUDIES OF WATERFOWL IN BRITISH COLUMBIA

### GREEN-WINGED TEAL<sup>1</sup>

BY J. A. MUNRO<sup>2</sup>

#### Abstract

The migrations of the Pacific Coast population of *Anas carolinensis* parallel in time and space those of *Anas acuta*. Both use the same migration routes along the coast and along the main north and south river systems of the interior. So also both nest more commonly in Alaska than elsewhere. The peak of the spring migration usually is reached in late March or early April; the peak of the autumn migration usually is in late October and early November. A relatively large number normally winter on the Coastal Plain. Very few winter in the interior. Study of banding data reveals that (1) autumn transients through the Coastal Plain follow the coast route south to the mouth of the Columbia River and beyond through Oregon and California, rarely passing east of the High Sierras, (2) few individuals among the population following interior routes reach the coast, the tendency being to swing eastward to the Great Basin. The two main flyways through British Columbia, one on the coast the other through the interior, differ in at least one important respect, viz., along the interior route are many more or less isolated areas of suitable nesting grounds whereas on the coast there are none. A small nesting population, fluctuating annually in numbers, is widely distributed through the interior, the center of abundance being the Cariboo Parklands—the term abundance being used in a relative sense. Actually the population is small and dispersed. In the year 1938 a total of only 17 broods was counted on a study area of 60 sq. mi. containing a high average of highly productive waterfowl territory. Smaller counts were made here in each of the years following 1938. Egg-laying begins in May; there is some loss of early clutches through crow predation compensated for by later, and usually more successful, nesting. It is not unusual for females to be incubating a second clutch of eggs in early July. Nest sites are in dry places nearly always adjacent to a small pond or marsh in the grasslands. The earliest and latest dates for records of downy young are June 20 and Aug. 10. The average number of young in 48 broods counted in July, and 17 broods counted in August, was the same viz. 6.2. This high survival rate may be attributed in part to the spirited defense of young commonly practised by the female parent. Adult males in small number may associate on a common loafing place during the egg-laying period, and for a week or so after incubation has started. Later they retreat to marsh habitat and begin the yearly molt. Full eclipse of the body plumage usually is attained prior to renewal of the flight feathers. The molt from eclipse to nuptial dress is not completed until late October. The first adult plumage of young males is not fully attained until January. The sex ratio appears to maintain a not unfavorable biological balance—a total of 4264 banded green-winged teal was composed of 2225 males and 2039 females. The food range of the species is not extensive. Seeds, chiefly those of aquatic plants, were present in the stomachs of all 69 adults examined, and in many constituted the bulk of food eaten. Insects are second, miscellaneous animals third, in importance. The green-winged teal is a valuable game species; none of its habits is detrimental to agricultural or other human interests.

#### Introduction

The green-winged teal, *Anas carolinensis* Gmelin, is one of the more common pond ducks in British Columbia, its numerical status probably equal to that of the pintail, *Anas acuta* Linnaeus. It winters on the Coastal Plain of British Columbia and Washington, south through Oregon, California, and the

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southwestern States to Mexico. In more northern latitudes of British Columbia winter populations are small, and in southern interior waters only a few individuals remain through winter.

The southern limit of the nesting range is central California, where it is scarce (5) and southcentral Oregon, from where no recent records are

TABLE I

NUMBER OF GREEN-WINGED TEAL BANDED IN BRITISH COLUMBIA AND TOTAL RECOVERIES

Banding periods	Number banded				Total recoveries	Recovery, %
	♂	♀	Not sexed	Totals		
<b>Station 1</b>						
1931, Nov. 3 - Nov. 15	29	30		59	7	11.86
Dec. 8	9	4		13	1	7.69
1932, Oct. 16 - Oct. 30	70	106		176	20	11.36
Nov. 2 - Nov. 18	32	36		68	18	26.47
Dec. 4	2			2		
1933, Mar. 29 - Apr. 18	14	12		26	3	11.54
Oct. 4 - Dec. 12	240	184		424	70	16.51
1934, Jan. 28 - Feb. 2	67	75		142	3	2.11
Mar. 3 - Mar. 18	3	3		6	1	16.66
Oct. 17 - Dec. 3	55	62	128	245	36	14.69
1935, Mar. 10 - Apr. 5	131	110		241	24	9.95
Oct. 22 - Oct. 28				87	87	8.04
Nov. 11				15	15	
Nov. 27 - Dec. 13	3	2	83	88	4	4.54
1936, Jan. 7 - Jan. 25	7	7		14		
Mar. 13 - Apr. 6	86	68		154	13	8.44
Oct. 23 - Oct. 29	10	10	38	58	3	5.17
Nov. 7 - Dec. 3			289	289	14	4.84
Dec. 10 - Dec. 28	186	150		336	21	6.25
1937, Mar. 19	2	2		4		
Nov. 2 - Dec. 23			789	789	66	8.36
1938, Dec. 12 - Dec. 24			2	2		
1939, Feb. 2 - Feb. 22	3	2		5	1	20.00
Dec. 5 - Dec. 23			14	14	1	7.14
<b>Station 2</b>						
1933, Feb. 10 - Apr. 24	296	325		621	57	9.17
1934, Feb. 11 - Apr. 30	257	138		395	26	6.58
1935, Feb. 10 - Apr. 26	132	78		210	18	8.57
<b>Station 3</b>						
1932, Oct. 3 - Feb. 19, 1933			1201	1201	150	12.49
1933, Sept. 4 - Dec. 17			788	788	56	7.10
1934, Oct. 21 - Dec. 30	364	450		814	68	8.35
1935, Jan. 6 - Jan. 20	229	143		372	25	6.72
<b>Station 4</b>						
1931, Nov.			52	52	7	13.46
<b>Station 5</b>						
1932, Aug. 14 - Oct. 6			77	77	14	18.18
1933, Aug. 30 - Oct. 20			14	14	2	14.28
<b>TOTALS</b>	<b>2227</b>	<b>1997</b>	<b>3577</b>	<b>7801</b>	<b>736</b>	

reported (4). The northerly limit is northwestern Alaska, and it is from that territory that a large portion of the winter population on the Pacific Coast is derived.

Information relating to the distribution and migrations on the Pacific Coast Region, largely determined by the study of banding data, and observations of life history, behavior, and food habits in British Columbia are presented in this paper.

Five banding stations in British Columbia, operating at various times between 1931 and 1940, were successful to the extent of capturing and banding 7801 green-winged teal. Since then, 736 bands have been recovered, or examined on recaptured birds; 456 in the first 12 months after banding, the remainder as follows: second year—173; third year—54; fourth year—24; fifth year—13; sixth year—8; seventh year—4; eighth year—3; ninth year—1 (See Tables I to VII).

The geographical positions of the banding stations, and definitions of the terms used in discussing banding data, are presented in an earlier paper of this series (8).

TABLE II  
DISTRIBUTION OF TOTAL GREEN-WINGED TEAL RECOVERIES

Locality where recovered	Number	Locality where recovered	Number
Alberta	4	Nebraska	1
Alaska	35	Nevada	4
British Columbia	315	Oklahoma	1
California	41	Oregon	49
Idaho	2	Utah	3
Montana	3	Washington	276
New Mexico	1	Yukon Territory	1
		Total	736

### Distribution and Seasonal Movements

#### COAST REGION

The 7658 green-winged teal banded at Coast Stations 1, 2, 3, from 1931 to 1939, inclusive, resulted in a total of 713 recoveries as at Dec. 31, 1945. Of these 664 represent bands recovered from birds shot or otherwise killed, while 49 are records of birds retrapped at Coast Stations in subsequent banding seasons. Some of the last eventually were shot and again reported. Green-winged teal are on the Coastal Plain in numbers from late September until late March and the sum of banding operations over nine years covers this entire period. Thus the data from these operations provide a sampling of two seasonal movements, viz. (1) the autumn migration, September to November, inclusive, involving some birds that would winter on the Coastal Plain and others that would proceed farther south, and (2) the spring migration, February to April, inclusive, involving winter visitants to the Coastal Plain

TABLE III

RECOVERIES OF GREEN-WINGED TEAL, AUTUMN AND WINTER, ON COASTAL PLAIN, STATIONS 1, 3

Locality where recovered	Current recoveries	Later years	Locality where recovered	Current recoveries	Later years
<i>Banded at Station 1</i>					
British Columbia— Station 1	23	4	Washington Counties Whatcom	7	4
Sumas-Chilliwack Region		8	Skagit	24	26
Station 3	1		Snohomish	5	3
Mouth Fraser River	13	8	Island	2	4
Intermediate points	14	7	San Juan	1	
Pitt River Region	7	1	King	3	9
Vancouver Island		5			
<i>Banded at Station 3</i>					
Station 3	7	27	Whatcom	1	3
Mouth Fraser River	18	28	Skagit	4	40
Vancouver Island	4	20	Snohomish		12
Station 1		1	Island	1	7
Station 2	1	3	San Juan		1
Pitt River Region	5	1	King	1	5
Intermediate points	2	2			
Sumas-Chilliwack Region	2	1			
	97	116		49	114

TABLE IV

RECOVERIES OF GREEN-WINGED TEAL, AUTUMN AND WINTER, SOUTH, EAST, AND WEST OF COASTAL PLAIN, STATIONS 1, 3

Locality where recovered	Current recoveries	Later years	Locality where recovered	Current recoveries	Later years
Western Washington counties Clallam	3	8	Eastern Washington counties Chelan		
Jefferson		2	Yakima		5
Kitsap	1	1	Okanagan		2
Pierce		3			
Mason	1	1	Western Oregon counties Clatsop	4	9
Gray's Harbour		4	Columbia		3
Thurston	3	2	Washington		2
Lewis		1	Multnomah		5
Cowlitz		1	Marion		1
Clarke	4		Linn	1	1
Utah State		1	Lane	2	2
Montana	1	1	Coos	2	4
Nevada			Totals	29	84
California	11	19			

TABLE V

RECOVERIES OF GREEN-WINGED TEAL ON COASTAL PLAIN, AUTUMN AND WINTER FROM SPRING BANDING, STATIONS 1, 2, 3

Locality where recovered	First year	Later years	Locality where recovered	First year	Later years
<i>Banded at Station 1</i>					
British Columbia			Washington counties		
Station 1	3	2	Whatcom	5	3
Sumas-Chilliwack Region	2		Skagit		6
Pitt River Region	1		Snohomish		2
Mouth Fraser River	2	1	King	1	1
Vancouver Island	3	1			

*Banded at Station 2*

Pitt River Region	6	5	Whatcom	12	1
Station 3	1		Skagit		8
Mouth Fraser River	7	4	Snohomish	2	1
Intermediate points		1	Island	2	3
Vancouver Island	1	4			

*Banded at Station 3*

Station 3	15		Skagit	2	1
Mouth Fraser River		1	Snohomish		
Intermediate points		2			
Vancouver Island	1	1			
Totals	42	22		24	27

TABLE VI

RECOVERIES OF GREEN-WINGED TEAL, SOUTH, EAST, AND WEST OF COASTAL PLAIN, FROM SPRING BANDING, STATIONS 1, 2, 3

Locality where recovered	First year	Later years	Locality where recovered	First year	Later years
Western Washington counties			Eastern Washington counties		
Clallam	1	7	Yakima		1
Jefferson		1			
Pierce		1	Western Oregon counties		
Gray's Harbour	1	1	Clatsop	3	2
Clarke	1	2	Columbia	1	1
Idaho State		1	Multnomah	1	2
Utah		1	Linn	1	
California	4	4	Totals	13	24

that were about to migrate, and others, from wintering places farther south, that had begun the journey to northern nesting grounds. As the periods of autumn and winter banding included the times in which it was lawful to

TABLE VII  
RECOVERIES OF GREEN-WINGED TEAL NORTH OF COASTAL PLAIN,  
STATIONS 1, 2, 3

Locality where recovered	First year	Later years
British Columbia		
West coast Vancouver Island	4	6
Mainland Coast	2	4
Goose Island	1	
Calvert Island		1
Graham Island		1
Southern Interior	3	
Central Interior	5	
Northern Interior	2	4
Yukon Territory	1	
Alaska	17	17
Alberta	3	1
Totals	38	34

hunt ducks, current recoveries were numerous during that season, but during the period of spring banding it was unlawful to hunt ducks so no current recoveries resulted.

In view of the large percentage of current recoveries resulting from autumn and winter banding, and the absence of current recoveries from spring banding, it has seemed advisable to tabulate the data in the following categories:

- Table III. Recoveries on Coastal Plain from autumn and winter banding, Stations 1, 3; current 146, later years, 230.
- Table IV. Recoveries, autumn and winter, south, east, and west of Coastal Plain, Stations 1, 3; current 29, later years 84.
- Table V. Recoveries on Coastal Plain from spring banding, Stations 1, 2, 3; first year 66, later years 49.
- Table VI. Recoveries, south, east and west of Coastal Plain from spring banding, Stations 1, 2, 3; first year 13, later years 24.
- Table VII. Recoveries north of Coastal Plain, Stations 1, 2, 3; first year 38, later years 34.

#### *Autumn Migration*

An early flight of no great volume takes place in September; the larger movements are through October and November. D. A. Munro counted 52 on Burnaby Lake, Sept. 21, 1946, and considered them to be the first autumn migrants (MS.). Later counts made by him at that place are: Oct. 6, 1946—305; Oct. 4, 1948—168 (in litt.). J. Tener counted 79 on Lulu Island, Sept. 10, 1947 (in litt.). It is of value to note here that in 1948 the earliest date of

arrival in force on the Suisun State Waterfowl Refuge, San Francisco Bay Region, Calif., is Sept. 18, when 1200 were counted. Many populations travelling either by the coast or by the interior would seem to continue south with few stops en route.

The Coastal Plain, flanked on two sides by high mountain ranges, lies athwart a main highway of migration between northern nesting grounds and southern wintering grounds. Here large concentrations of ducks take place in a relatively small area and here migrating waterfowl are subject to an intense hunting pressure that is perhaps without parallel in any other section of the Pacific Flyway. It is not surprising then that 491, or 69.84% of total recoveries from coast banding come from this small geographical area. The times in which the largest numbers of bands were recovered can be assumed to be the times of maximum migratory movement. In three consecutive years this maximum was attained in November, as is shown in the tabulation below.

NUMBER OF RECOVERIES ON THE COASTAL PLAIN IN THREE CONSECUTIVE YEARS

	October	November	December	January
1933	34	57	37	6 (1934)
1934	13	48	30	19 (1935)
1935	15	54	19	10 (1936)
Totals	62	159	86	35

### Winter

The winter distribution of the green-winged teal on the British Columbia portion of the Coastal Plain parallels that of the pintail (9). The two species have similar food habits and a similarly limited food range, with preference shown for aquatic insects and seeds of both terrestrial and aquatic plants. The green-winged teal has not been observed feeding on waste grain in stubble fields, nor on stooked grain, as the more adaptable mallard does and in so doing extends the limit of its winter range. Nevertheless the green-winged teal does eat grain readily under some circumstances, for example when the grain is softened by water, or when it is available within easy reach of water. The natural food items are available in abundance only when flood ponds, shallow streams, and lakes remain open, a condition that, on the interior parts of the Coastal Plain, may persist throughout the winter in some years and at irregular intervals in others. Thus the species' movements within the region, and the size of the winter population in any year, are controlled by weather conditions to the same extent as are movements of the pintail.

The green-winged teal winter population is larger than that of the pintail so that its movements more often come under observation. Thus a shift of population from the Chilliwack-Sumas region to the coast, because of freezing conditions in the interior section, is sometimes obvious. Thus in 1933 a

mass movement to the coast took place in early December, and a large part of the population sought refuge on an artificial lake at Station 3, near the mouth of the Fraser River, where at that time ducks were being fed some 600 lb. of barley each day. On Dec. 13 it was estimated that between 10 and 12 thousand green-winged teal, together with smaller numbers of mallard and pintail, were on this property. Station 1, near Chilliwack, had been closed on Dec. 12 because of cold weather and a scarcity of ducks. A similar western movement is revealed in the banding data for 1934. During the period Oct. 21 to Nov. 21 in that year banding results at Station 1 and Station 3 were comparable, viz., 244 and 309 respectively. On Dec. 1, after an unsuccessful week due to freezing conditions, Station 1 was closed; Station 3 continued to operate with greatly increased catches, a total of 804 green-winged teal being taken from Dec. 4 to Jan. 20.

Recent estimates of some local winter populations in British Columbia are available as a result of the "January Waterfowl Inventory" in which local ornithologists and Provincial Game Wardens participated. The figures for 1947, 1948, and 1949 are set out below:

	1947 (Jan. 7-17)	1948 (Jan. 7-10)	1949 (Jan. 11-14)
<b>Coastal Plain</b>			
Chilliwack-Sumas Region	5	19	0
Burnaby Lake	80	0	0
Fraser River Mouth to Boundary Bay	4500	3600	3200
Pitt Meadows	—	400	0
S.E. Vancouver Island	1600	300	500
Burke Channel, Fitzhugh Sound	—	300	300
West Coast, Vancouver Island	—	1300	—
Graham Island	100	100	—

Whatever weather conditions may prevail, the population wintering on the Coastal Plain, in recent years at least, is smaller than the population wintering on the Central Plain of California, usually a frost-free area and consequently an important wintering ground. The dates for first arrivals and for peaks of population at the Sacramento National Wildlife Refuge are set out below (Vernon Ekedahl, Refuge Manager, in litt.):

Year	Arrival in autumn	Number	Peak of population	Number
1943	Aug. 20	25	Dec. 22	4700
1944	" 16	250	" 19	25,000
1945	" 17	50	" 29	5300
1946	" 25	25		
1947			Sept. 22	13,600
1948	" 21	600	Jan. 8	58,210

Monthly totals of green-winged teal recovered along the Columbia River in southwestern Washington and Oregon, in southern Oregon, and in California are: October—9; November—31; December—49. Thus the arrival of these ducks in force on southern wintering grounds parallels in time the movement of large numbers from interior parts of the Coastal Plain to the sea coast, which usually takes place in late November and in December. An example of this movement, correlated with a sudden drop in temperature, was noted earlier.

The following are examples of green-winged teal banded at Stations 1 and 2 and recovered in the current year south of the Coastal Plain (see also Fig. 1):

Date banded	Locality where recovered	Date recovered
Oct. 16, 1933	Sutter Co., Calif.	Dec. 30, 1933
" 16, "	Sutter Co., Calif.	" 30, "
" 16, "	Thornton, Calif.	" 17, "
" 25, "	Sauvie's Island, Ore.	Nov. 29, "
" 27, 1934	Butte Co., Calif.	Dec. 8, 1934
" 27, 1936	Seaside, Ore.	Nov. 2, 1936
" 30, 1932	Humboldt Co., Calif.	Dec. 24, 1932
Nov. 3, 1933	Suisun Marshes, Calif.	Dec. 27, 1933
Nov. 4, 1937	Modoc Co., Calif.	Dec. 17, 1937
" 7, 1932	Marshfield, Ore.	" 8, 1932
" 11, 1933	Santa Rosa, Calif.	" 28, 1933
" 11, 1932	North Bend, Ore.	" 11, 1932
" 21, 1934	Eugene, Ore.	Nov. 25, 1934
" 26, 1933	Clear Lake, Calif.	Dec. 25, 1933

It has been stated elsewhere (8, 9) that a large percentage of the recoveries of mallard and pintail were made on the Coastal Plain during the first few weeks after banding. The same high percentage of local early returns is observed in connection with the banding of green-winged teal. Thus, of 111 current recoveries of birds banded at Station 1, 91 are from the Coastal Plain, 28 being taken the first week, 21 in the second week, 11 in the third week, and 31 in periods of from four to nine weeks after the date on which the duck was banded.

Of the 28 first-week recoveries, 14 are from localities within a 20 mi. radius of the Station, two are from the Pitt River Region, 35 mi. west, four from places adjacent to the mouth of the Fraser River, 50 mi. west, one from Whatcom County, Wash., 30 mi. southwest, and seven from Skagit County—the farthest flight southwest being to Padilla Bay, 50 mi. distant from the Station, where one green-winged teal was shot two days, another seven days, after banding.

The 22 recovered during the second week came from the following localities: seven from points within a 20 mi. radius of the Station, four from the Pitt River Region, four from points near the mouth of the Fraser River, one from Snohomish County, four from Skagit County, and two from King County. The longest flight was to a locality 15 mi. south of Seattle, Wash., a distance of 120 air-line miles.

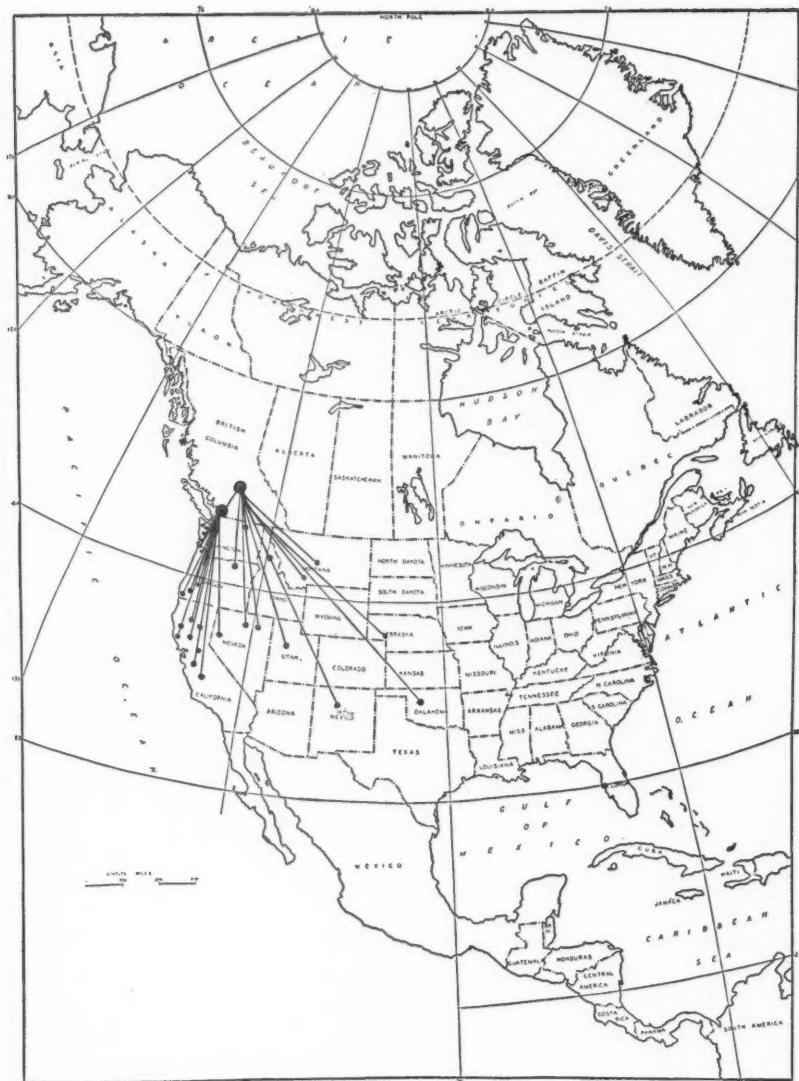


FIG. 1. Current recoveries of transient green-winged teal banded at Stations 1, 3 (left), and Station 5 (right). Each dot represents one or more recoveries.

Of the 11 bands recovered during the third week five are from localities within a 20 mi. radius, three from the Fraser River mouth, and one from each of the counties Whatcom, Skagit, and Snohomish.

The remaining 30 bands, recovered at later periods, come from the same general localities, all within an extreme distance of 120 mi.

To be considered here, also, are 246 recorded occurrences of green-winged teal recaptured at Station 1 during the current banding season in the years 1932-1937, inclusive. One hundred and thirty-seven were taken one to six days after banding, the remainder after elapsed periods approximately as follows: one week—43; two weeks—27; three weeks—19; four weeks—10; five weeks—8; six weeks—1; seven weeks—1. The total of 246 is a fraction of a larger number captured but not recorded.

The foregoing data give some idea of the extent to which winter populations move from place to place within the Coastal Plain. In addition the data designated as current trap-recoveries afford evidence as to the length of time certain couples or groups remain within the vicinity of the Station. For example: two banded Nov. 12, 1936, were recaptured Dec. 3, 1936; three banded Nov. 19, 1937, were recaptured Dec. 12, 1937, and two banded Nov. 6, 1937, were recaptured Dec. 10, 1937. It may be inferred that these particular groups wintered in the vicinity of the Station.

Four instances of a westerly flight over the Gulf of Georgia from Station 3 to Vancouver Island are recorded, the particulars being as follows:

Date banded	Locality where recovered	Date recovered
Jan. 23, 1933	Ladysmith	Jan. 1933
" 10, 1935	Victoria	Jan. 21, 1935
Jan. 13, 1935	Crofton	Jan. 18, 1935
Jan. 13, 1935	Clayquot	Jan. 30, 1935

As was done in a study of the pintail (9) the subsequent history of certain green-winged teal that have been recovered and that represent the total of returns from one day's banding at a single station has been assembled. Three samples of this grouped data follow.

#### *Station 1*

A total of 40 recoveries are reported from a group of 142 green-winged teal banded Nov. 4, 1939. In the same year 14 were recaptured and released at Station 1 on Nov. 6; four were recaptured on Nov. 8, and single birds were recaptured on each of the following dates: Nov. 13, Nov. 29, Dec. 4, and Dec. 11. One was taken again on Nov. 3 and Dec. 8, another on Nov. 6, Dec. 8, and Dec. 12. The following were shot: one at Lulu Island, Nov. 5; one at Matsqui, Nov. 22; one at Sumas (B.C.), Dec. 11; six in Skagit County, Wash., between Nov. 9 and Dec. 3, and one in Modoc County, Calif., on Dec. 17. In 1938 one was shot Nov. 13 at St. Helena, Columbia County, Ore.; another on Nov. 8 at Vancouver Lake, Wash.

#### *Station 2*

A total of eight recoveries are reported from a group of 137 banded on Mar. 10, 1933. In 1933 one was recaptured and released at Station 2 on Apr. 11; one was shot at Pitt River on Oct. 12, another at Camano Island,

Wash. on Oct. 22, and two at Ladner on Nov. 11. In 1934 one was shot at Pitt River on Jan. 14, one at Valdez, Alaska, on Sept. 14, another at Sauvie's Island, Ore., on Dec. 7.

#### *Station 3*

A total of 20 recoveries are reported from 242 green-winged teal, banded on Jan. 13, 1935. Four were shot later in the same month, two near the banding station, one at Clayquot Sound and another at Crofton, Vancouver Island. In the following May one was recovered about 200 mi. north of Hazelton, B.C. In the autumn and winter of 1935 six were shot on the Coastal Plain, one at the mouth of the Fraser River, one at Pitt Meadows, two near Olympia, Wash., on the same date, viz., Oct. 23, and two in Skagit County, Wash. In 1936 two were taken at Shawnigan Lake on Feb. 18, and one was shot at Chemainus on Nov. 23—both these places are on Vancouver Island.

A total of 26 recoveries have been reported from an unknown number banded at Station 3 on Feb. 5, 1933. One was shot at Kanatak, Alaska, the following April and in the autumn and winter of that year one was taken at Goose Island, one at Fort Simpson, B.C.; two in Skagit County, Wash.; one in Clallam County, Wash.; three in Clatsop County, Ore.; 11 were recaptured and released at Station 3 on the following dates, viz., Oct. 21—1; Nov. 1—1; Nov. 26—4; Dec. 3—3; Dec. 10—2; and one was shot near the Station on Nov. 12. In the autumn and winter of 1934 one was shot in Skagit County, one in Clark County, Wash.; one near New Westminster, B.C.; and one near Nanaimo, Vancouver Island. In 1935 one was shot in Snohomish County, Wash., Nov. 2, and one near Surrey, B.C., on Dec. 1.

Many green-winged teal that escape early destruction return to the same localities in succeeding years. Table III shows that 67 in a total of 230 subsequently returned to Stations 1 and 3 where they were banded, or to places within a 20-mi. radius of these Stations. When assembled in year groups the data reveals that 35 were recovered in the autumn and winter of the first year, that is to say after they had made one journey to and from their nesting grounds, and 32 were recovered in the second year. None were taken subsequently at or near these stations.

The date on which green-winged teal were banded in one year and the date on which they were recovered in the following year are, in some instances, in the same month, close enough to suggest an approximate time of arrival in each year, the difference in time perhaps being modified in some degree by differences in the prevailing weather conditions. While the first seasonal recorded appearance of an individual does not necessarily mean that the bird had just arrived, nevertheless there is a strong possibility of this being so. For the first few days after units of population reach the Coastal Plain, possibly because of a recent protracted flight and a degree of exhaustion resulting from it, ducks are commonly much less wary than at other times, so consequently are more eager to enter banding traps where food is available, and also much more likely to be shot.

The following records are of green-winged teal banded at Station 3 and recaptured there, or shot within a 20-mi. radius, in the following year.

Date banded	Date recovered	Date banded	Date recovered
Dec. 8, 1932	Dec. 3, 1933	Dec. 18, 1932	Dec. 3, 1933
" 11, "	Nov. 19, "	" 20, "	Nov. 19, "
" 15, "	Oct. 29, "	" 20, "	Dec. 3, "
" 15, "	Nov. 2, "	" 20, "	" 3, "
" 15, "	" 26, "	" 20, "	" 10, "
" 18, "	" 11, "	Nov. 5, 1933	Oct. 24, 1934
" 18, "	" 19, "	" 5, "	Nov. 14, "
" 18, "	" 26, "	" 11, "	Oct. 24, "

The above is acceptable evidence that units of populations return to the same localities on the Coastal Plain, a conclusion borne out by numerous instances of couples or groups that, banded together on the same day, were later recaptured together, some after a period of several weeks.

Number in groups	Date banded	Date recaptured
2	Mar. 12, 1933	Apr. 18, 1933
7	" 19, 1935	Mar. 25, 1935
2	" 19, 1935	Apr. 1, 1935
4	" 25, 1935	Apr. 1, 1935
2	Nov. 12, 1936	Dec. 3, 1936
3	" 19, 1936	Nov. 29, 1936
3	" 19, 1936	Dec. 10, 1936
14	" 4, 1937	Nov. 6, 1937
3	" 4, 1937	Dec. 13, 1937
2	" 6, 1937	Dec. 10, 1937

Population cohesion is illustrated with equal emphasis by other data in reference to couples, or groups, which return to the Station at which they were banded after an absence of one year. All the examples shown in the tabular material on p. 162 are of green-winged teal banded at Station 3.

The summaries indicate that the large flocks of green-winged teal visiting the Coastal Plain are composed of aggregations of small populations each of which exhibit definite cohesion. It can be anticipated that extensive banding operations along the flyways and on nesting grounds will add further evidence in support of the conclusion advanced here.

#### *Spring Migration*

A concentration of green-winged teal on the Coastal Plain prior to migration has been observed and is apparent in banding data. Thus at Station 2 in 1933 the daily total of birds captured increased from 13 on Mar. 9 to 137 on Mar. 10 and 47 on Mar. 11. The number dropped to 12 the following day, and thereafter the largest daily catch until Apr. 13, when operations ceased, was 29 on Apr. 9. Similarly at Station 1 in 1935 the largest number taken

during a four-day period in spring, Mar. 19 to 22, was 114. Subsequently, until the Station was closed on Apr. 15, a total of only 71 was captured.

Number in groups	Date banded	Date recaptured
2	Nov. 27, 1932	Oct. 29, 1933 Dec. 3, "
3	Dec. 11, "	Oct. 21, " Nov. 19, " (2)
2	Dec. 15, "	Oct. 29, " Nov. 26,
5	Dec. 18, "	Nov. 11, " " 19, " " 26, Dec. 3, " Jan. 20, 1935
4	Dec. 20, "	Nov. 19, 1933 Dec. 3, " " 10, "
4	Jan. 29, 1933	Nov. 11, 1933 " 26, Dec. 3, " " 10, "
11	Feb. 5, "	Oct. 21, " Nov. 12, " " 26, " (4) Dec. 3, " (3) " 10, " (2)

Field observations indicate that, by the first week in April, the main migration has passed, leaving only a few small units and finally most of these also leave for northern nesting grounds. There is a lack of observational data concerning the spring migration along the northern coast, there being but two counts available, both from the Queen Charlotte Islands, viz., McClinton Creek, Apr. 15, 1935—30, and Tlell, May 5, 1935—20.

#### Summer

Summer records of green-winged teal on the Coastal Plain in British Columbia are not uncommon. For example, a small population frequents Burnaby Lake and, in 1946, the numbers were recorded throughout the summer, the largest counts being May 21—8, June 12—4, July 6—7, Aug. 19—7 (D. A. Munro, MS.). Another population is reported from Lulu Island where the following counts were made in 1947: May 14—6, June 2—1, June 14—3, June 17—4, July 4—11, Aug. 1—7, Aug. 25—16, Aug. 26—35, Aug. 27—22, some of the last probably being transients (John Tener, in litt.). The investigators were of the opinion, after close study of these two areas, that neither population included any breeding pairs. Green-winged teal are reported to have nested in the vicinity of Vancouver (3) and in the vicinity

of Chilliwack (1), but in neither account is satisfactory evidence submitted. It seems clear then, that all, save a small residue probably composed of non-breeding birds, migrate beyond the limits of the Coastal Plain. Banded green-winged teal have been taken at many places on the coast and in the interior of Alaska, indeed a majority of the recoveries (89.5%) from north of the Coastal Plain come from there (see Table VII), and there is little doubt that Alaska is the principal nesting ground of the west coast population. The localities in that territory, and the number of bands recovered at each place are: Akiachak—1; Becharof Lake—1; Bristol Bay—1; Cook Inlet—2; Chulitna River—1; Dillingham—1; Goodnews—1; Iditarod—1; Kaltag—1; Kenatak—1; Katalla—1; Koyuk—1; Koyukuk—2; Kuskokwun River mouth—1; Kwigillingok—1; Mountain Village—1; Nunachuk Village—1; Perryville—1; Pilot Station—1; Sitka—2; St. Michael—1; Steelmute—1; Seward Peninsula—1; Tanana Crossing—1; Togiak River—1; Valdez—2; Yukon River—2; Yukon Delta—2.

#### INTERIOR REGION

##### *Spring Migration*

As compared with the spring migration from the Coastal Plain along the coast to Alaska the migration north through the Interior is relatively small and some of the elements composing it are members of populations that nest in southern latitudes. The two main flyways, one along the coast the other across the Interior Plateau, have this important difference, viz., over much of the interior route are suitable nesting grounds used by this species, whereas along the coast there are none.

Through the southern part of the Province there appear to be five streams of migration tributary to the main flyway across the Interior Plateau. Populations that have wintered on the Coastal Plain follow the Fraser-Thompson system and the Columbia-Okanagan system; the two flight lines come together in the grassland region adjacent to Kamloops.

There is evidence of a third route, one via Howe Sound, Squamish, Pemberton Meadows, Anderson, and Seton Lake, but about this no precise data are available.

The Rocky Mountain Trench and the Purcell Trench in eastern British Columbia are migration routes used by populations of green-winged teal that apparently are distinct from those wintering on the Coastal Plain. There have been two recoveries on the Kootenay Flats, in the Purcell Trench, of green-winged teal banded at Malheur Lake in eastern Oregon, viz., one banded Apr. 5, 1933, was taken at Creston, Sept. 20, 1936; another banded Mar. 26, 1936, was taken at Wynndel, Nov. 4, 1938. None of the 7801 green-winged teal banded in British Columbia have been taken in the eastern portion of the Province.

The first of the Eastern routes mentioned is known to follow the Columbia Valley, of which the southern portion contains many suitable resting and feeding places, at least as far north as Golden. It perhaps may be assumed

that the route then follows the general course of the river north across the Columbia Forest Biotic Area, where no suitable feeding places exist, to the Big Bend, and from there, where the Columbia River turns south, in a northwesterly direction probably following the Canoe and Fraser Rivers to the ponds and marshes of the Cariboo Parklands and to the grassland and aspen country beyond. The second route follows down the Kootenay River where resting and feeding places on the Kootenay Flats temporarily detain the ducks, to Kootenay Lake, and north over the swampy valley of the Lardo. After leaving the favorable territory of the Kootenay River and its tributaries, this route, also, presumably bears to the northwest.

There is little information as to the numbers of green-winged teal that pass through the Cariboo Parklands in the early part of any spring migration. A flock of 247 counted at Little White Lake, Apr. 29, 1938, was considered to be the last of the spring flight for that year.

At Chezacut Lake, in the Chilcotin District, the earliest records are of 40 on Apr. 18, 1940, and 20 on Apr. 23, 1941. In the Lakes District of Vanderhoof, farther north in the Central Interior, the migration had passed through prior to May 1, 1945, except a few belated flocks, of which one of 10 and another of 17 were noted on May 6. The only spring banding returns from the Central Interior Region is that of a male banded at Station 1 on Apr. 11, 1933, and killed that spring on Lake Uncha, near Danskin, which is on Francois Lake.

Spring migration data in more northern parts of the Province refer to Tetana Lake where, in 1941, the first was seen on Apr. 8 (11) and to Atlin where the earliest spring records are reported to be Apr. 30, 1933, Apr. 20, 1934, and Apr. 22, 1935 (14).

The particulars of three banded green-winged teal recovered in northern British Columbia are:

Banding Station	Date banded	Locality where recovered	Date recovered
Station 1	Dec. 4, 1937	Buckley Lake, 20 mi. SE. Telegraph Creek	Spring, 1938
Station 2	Mar. 4, 1935	Rolla, 12 mi. N. Peace River	Apr. 23, 1935
Station 3	Dec. 20, 1935	Driftwood River, near Takla Landing	May 14, 1937

In summary, the spring migration of the green-winged teal through the Central Interior follows closely in time behind that of the pintail, with the maximum number in transit between Apr. 1 and Apr. 15.

#### *Autumn Migration*

The rapid flight of green-winged teal, and the uniform timing of movement of the individuals composing a flock, characteristic of the species at any time, seems more apparent, and a source of admiring comment, during the autumn

migration. Very often these ducks travel in small flocks of 10 to 30 individuals and a number of such units, usually composed of the season's young, may combine to form a company of 100 or more. Such a transient flock may assemble on a muddy shore, and nervously alert, may rise suddenly, ascend to a height, fly in a wide circle, descend spirally with a sharp whistle of wings, wheel out over the water, then alight once more—all these movements being performed with the speed, the grace, and the precision of a flock of sandpipers. Green-winged teal associate freely with mallard and with pintail, occupy the same mud bars, tidal flats, and other loafing places, and feed under cover in the bulrush marshes that mallard frequent.

The first wave of the autumn transients usually appears in early August, often two weeks or a month earlier than the first transients appear on the Coastal Plain.

Observations and records of the autumn migration through the interior are summarized in the following paragraphs:

Atlin. The latest recorded observation of green-winged teal in autumn is Oct. 5, 1931 (14).

Kispiox Valley, on the Kispiox River at a point 23 mi. north of Hazelton. In 1921 the first autumn transients were observed Aug. 10 (13).

Vanderhoof. In the Lakes District in 1945 a flock of  $60 \pm$  was observed on a marshy slough, Aug. 31. In 1946 the first indications of a southern migration was a flock of 25 in flight over Sinkut Lake, Aug. 25. There are two banding returns from this locality, viz., one banded at Station 2, Mar. 23, 1934, was shot at Nulk Lake, Sept. 12, 1934; another banded at Station 1, Nov. 6, 1937, was shot on the Nechaco River, Oct. 29, 1938. Thus the three records give a possible migration period from Aug. 31 to Oct. 29.

Cariboo Parklands. From the 91 green-winged teal banded at Buffalo Lake, Station 5, in the autumn seasons of 1932 and 1933 (See Table I), 16 bands have been reported—one from Alaska; two from near the mouth of the Columbia River in Washington State; and 13, of which 12 are current recoveries all but one from southern interior localities. These data, being of exceptional interest in that they show a first-season wide dispersal over the Great Central Basin and eastward (see Fig. 1), are submitted in full, as shown in the tabular material at the bottom of p. 166.

Buffalo Lake, in the Cariboo Parklands, is on the main flight-line of the interior, north of where three tributary routes converge, thus the high percentage of banding returns from eastern localities is significant evidence of the small extent to which the Coastal Plain wintering population is represented on the interior flight-line (see Fig. 1). There is added significance in the fact that only 14 bands from green-winged teal banded at Coast Stations have been recovered in the interior of British Columbia. The details of those recovered in the Cariboo Parklands follow:

Station where banded	Date banded	Locality where recovered	Date recovered
Station 1	Nov. 13, 1932	Gang Ranch	Sept. 27, 1933
Station 1	" 3, 1933	North Bonaparte	Autumn, 1934
Station 2	" 26, 1933	Soda Lake, 108 Mile Ranch	Oct. 11, 1934

Okanagan Valley. The earliest evidence of an autumn migration in any year refers to a flock of 75 on Goose Lake, near Vernon, Aug. 10, 1919.

The adjacent Swan Lake is the most important resting and feeding place for green-winged teal in the Okanagan Valley and here the maximum autumn concentration usually takes place during the period Sept. 15 to Oct. 15; more rarely it is not attained until early November. The following enumerations are of maximum numbers recorded in each of nine years: Sept. 15, 1932—300±; Sept. 30, 1933—400±; Oct. 4, 1934—275±; Nov. 5, 1942—200±; Oct. 10, 1943—30±; Sept. 10, 1946—41; Oct. 6, 1948—120±.

Fifty-two green-winged teal were banded in Nov., 1931, at Vaseaux Lake, in the southern part of Okanagan Valley, and seven bands were recovered later. Two were local, current recoveries, and two local recoveries in Dec., 1932; one records the interesting information that a male banded on Nov. 7 was shot 28 mi. north of the banding Station on Dec. 3. One is a second year recovery from California, and another records that a male banded Nov. 7 was shot in Klamath County, Ore., on Dec. 20 of the same year.

Date banded	Locality where recovered	Date recovered
Aug. 25, 1932	Yakima Co., Wash.	Dec. 2, 1932
" 25, "	Albuquerque, N. Mex.	" 10, "
" 30, "	Hat Creek, Nev.	Nov. 19, "
Sept. 1, "	Pacific Co., Wash.	Jan. 1935
" 2, "	Holitna River, Alaska	May, 1934
" 2, "	Cache Co., Utah	Oct. 8, 1932
" 2, "	Whitefish, Mont.	" 2, "
" 4, "	Los Angeles, Calif., 40 mi. south	Nov. 1933
Sept. 6, 1932	Nelson, Calif.	Dec. 12, 1932
" 15, "	Kalispell, Mont.	Oct. 1, 1932
" 16, "	Hot Springs, Idaho	Jan. 16, 1932
" 16, "	Nye Co., Nev.	Oct. 1, 1932
" 17, "	Wahkiakum Co., Wash.	Oct. 1932
Oct. 7, "	North Powder, Ore.	Oct. 23, 1932
Sept. 19, 1933	Kingfisher, Okla.	" 22, 1933
" 19, "	Valley, Neb.	" 13, "

West Kootenay. At Sirdar Lake on the Kootenay Flats two autumn migrations were tallied as follows:

1947		1948	
Date	Number of birds	Date	Number of birds
Aug. 7	6	Aug. 19	23
" 26	350±	" 27	85
" 29	250±	" 29	270±
Sept. 8	600±	Sept. 5	80
" 10	800±	" 8	70
" 11	350±		

East Kootenay. Dates for early arrival of transients at Golden in the Columbia Valley in 1948 are: Aug. 17—20; Sept. 6—48 (D. A. Munro, in litt.).

It will be valuable at this point to consider data in reference to migrations south of the International Boundary. The first wave of autumn migrants usually reaches the Tule Lake National Wildlife Refuge in northern California, and the adjacent Lower Klamath Lake National Wildlife Refuge in southern Oregon, sometime during the last two weeks of August, peak numbers normally being recorded in October. Later with the first prolonged cold spell comes an abrupt decline in numbers and relatively few remain through winter (Howard Sargeant, Refuge Manager, in litt.). Dates of arrival in force and dates of maximum numbers are tabulated below.

First arrival in force	Peak numbers attained
<i>Tule Lake National Wildlife Refuge</i>	
1945	Oct. 28—50,000
1946 Aug. 31—5000	" 15—20,000
1947 " 31—2000	" 10—18,000
1948 Sept. 20—2500	" 31—15,000
<i>Lower Klamath Lake National Wildlife Refuge</i>	
1945 Sept. 10—2500	Oct. 28—10,000
1946 Aug. 31—3000	" 15—25,000
1947 " 31—2500	" 10—45,000
1948 " 30—3500	" 20—20,000

Summarizing the above section it can be said that in general the autumn migration through the interior takes place from early August to late October; a large migration in November was observed once only. Autumn and winter current recoveries of green-winged teal banded at Buffalo Lake suggest that

the largest number using this flight-line are transients to and from southern interior localities, while a much smaller number is associated with the Coastal Plain.

### Reproduction

In summer the green-winged teal is widely distributed through the interior of British Columbia from near the International Boundary to Atlin in the extreme northwest part of the Province. The populations are small, particularly so in the south from where but few nests or broods have been recorded. A female accompanied by eight young three-quarters grown was observed on the Kootenay Flats, Aug. 18, 1947, and three nests with eggs are reported from the east Kootenay, viz., two at Cranbrook Slough, examined by W. B. Johnstone, June 8, 1939 (MS.) and one found near Fairmont Hot Springs, June 14, 1948 (D. A. Munro, in litt.). It is reported to have nested near Edgewood, in the west Kootenay (6) and there are three records of broods from the Okanagan Landing region, viz., one of half-grown young, June 23, 1915, and two late broods of downy young, Aug. 10, 1919. No recent breeding records from the Okanagan Valley are reported.

The Cariboo Parklands in southcentral British Columbia attract a relatively large nesting population, but one that shows marked fluctuation in numbers from year to year. The following record of broods observed, while by no means indicating the totals of population in different summers, reflects in some measure the extent of this fluctuation.

1936	1937	1938	1939	1941	1942	1943	1944	1948
2	6	39	7	2	2	2	2	2

On a sample study area of 60 sq. mi. containing the most productive nesting grounds, the total counts were 45 adults and 17 broods in 1938, and 12 adults and two broods in 1948.

On the Endako River drainage small numbers have been found nesting, or with broods, in the vicinity of Vanderhoof, Francois Lake, and Ootsa Lake. A summer population is reported from the Driftwood Valley, approximately 175 mi. to the northwest of Vanderhoof (12) and, at Swan Lake and Charlie Lake in the Peace River Block, five broods of young were counted, June 8, 1938 (2). At Atlin, where the species is reported to be a "common summer resident", a brood of downy young was observed, July 13, 1934 (14).

During the mating season pairs of green-winged teal frequently have been flushed, or have been seen rising in display flight, from areas of open water hidden by dense marsh growth. It seems likely that courtship, other than display flight, is commonly practised in such concealed places; however that may be, no mated birds, nor groups of both sexes, have been observed in courtship display on beaches or on open water. Neither has any hostility among the males been noted. During the laying season it is not unusual to see several males idling on the surface of some secluded marsh pond, or standing together on its muddy shore, on a half-submerged log, or on some other slight

prominence as they await the arrival of the females from the nests. The actions of the males, and their apparent lethargy, in the laying season is in marked contrast to the behavior of both blue-winged teal and cinnamon teal, which are aggressive among themselves and constantly court and display in full view of a human observer.

In the Lakes District, Vanderhoof, during May, 1945, pairs, and trios composed of two males and one female, were frequently seen in courtship-flight, and in the latter part of May and early June it was common to see mated pairs together, the latest date recorded for this association being July 1.

#### Nesting

The preferred nesting habitat of the green-winged teal is one of grassland, sedge meadow, or dry hillside containing aspen or brush thickets, or open woods adjacent to pond or slough. The number of eggs in a clutch varies from six to nine, with an average of eight. (Broods of 10, 11, and 13 have been recorded, but these may be the product of more than one family. Thus at Mirage Lake, Aug. 1, 1938, one female led a brood of 13, another a brood of seven, while a third was accompanied by only one young.) No nests have been found at a distance greater than 250 yd. from water and usually the distance is much less; all those examined were in dry situations. The following examples are typical.

Horse Lake, Cariboo, May 10, 1943. Habitat, narrow belt of willows, alders, and aspen near the shore of a marshy bay; site, on open ground close to a dwarf birch, *Betula glandulosa*, at the inner margin of the tree belt; nest, a depression in the ground 6 in. in diameter containing a few dead leaves of dwarf birch and alder. It contained four eggs on May 10, five eggs on May 12, and six eggs on May 13, the last time the nest was examined.

Slough near Westwick Lake, Cariboo, July 3, 1948. Habitat, edge of aspen woods 60 ft. from small forest pond in which small sedges, grasses, and *Sagittaria* hid the water; site, under cover of procumbent juniper, *Juniperus scopulorum*; nest of dry grass and down; nine eggs.

Springhouse Prairie, Cariboo, July 8, 1941. Habitat, dry sedge meadow beside a small pond; site, in sedges 100 ft. from water; nest, a slight depression lined with dry sedge stems and a large amount of down around the eggs, and around the circumference of the nest to a height of 3 in. above the surface of the ground; eight eggs.

Manson's Slough, near Vanderhoof, June 17, 1945. Habitat, dry sedge meadow adjoining slough; site, in sedges 150 yd. from water; nest of dry grass mixed with down and feathers; six eggs, four of which had been destroyed by crows.

Tatley Slough, near Fairmont Hot Springs, East Kootenay. Habitat, dry, wooded hillside above slough; site, 250 ft. from slough against a small Douglas fir trunk, of which one branch 2 in. above ground level provided shelter; nest of grass and small amount of down set in bowl approximately 6 in. deep

and 7 in. in diameter; eight eggs subsequently eaten by a predator, probably a crow (D. A. Munro, in litt.).

#### *Crow Predation*

Instances of green-winged teal eggs eaten by crows have been mentioned. This predation would seem to occur more often in the early weeks of summer when nesting cover often is inadequate. In each of four raided nests the eggs had been fresh and the clutch incomplete; in one were two eggs, which, deeply buried in the down, remained intact. Clutches of eggs laid in June or early July, when cover vegetation has reached an advanced stage of growth, are much less vulnerable. Crow predation can be considered an adverse factor in green-winged teal reproduction in that a percentage of early-laid eggs are destroyed and that subsequent clutches, representing a second nesting, usually are smaller.

#### *Behavior of Nesting Females*

Before leaving the nest the female covers the eggs with down, if this has been added to the nest, otherwise with whatever material composes the nest lining. Thus when the nest at Horse Lake, described above, was first examined the eggs were covered by a few dry leaves, many of which lay in the nest cavity and on the ground beside it. Covered thus the eggs were effectually concealed and the nest completely merged with the surrounding litter. This particular teal was flushed three times from the nest at distances of 20 to 30 yd.; each time she uttered a thin, quacking note continuously as she flew. The nest, as has been noted, was situated at the inner edge of a tree-belt, which provided effective barrier between it and the water. The teal, upon leaving the nest, did not attempt to rise over the barrier but flew close to the ground for 50 yd. or so to where an opening led to the water, and through this opening she passed.

The eggs in the nest at Springhouse Prairie, noted earlier, were in an advanced stage of incubation. On July 8 and July 9 the setting teal did not flush until I had approached within 12 ft. of the nest.

#### *Behavior of Female with Brood*

Female green-winged teal defend their broods in a seemingly fearless manner, which the following examples illustrate, the first being the characteristic behavior when a brood is concealed in a lakeshore marsh and its hiding place is approached by canoe. At Watson Lake, Cariboo Parklands, June 30, a female rose from the marsh and flew out over the water, passing me within a few yards, then ascending slightly, turned about and made a short circle back across the marsh, presumably over the place where the young were hiding. She then flew directly towards me again and alighted within a few yards of the moving canoe there to swim ahead, sometimes in the ordinary manner, sometimes beating the water with extended wings. These actions were accompanied by a continuous, excited quacking. Meanwhile the brood completely eluded observation.

PLATE I



FIG. 2. Two female green-winged teal defending their combined broods.

PLATE II



FIG. 3. Brood of green-winged teal, about three-quarters grown and flightless, retreating to shore cover.

At Westwick Lake, July 7, 1941, a female surged back and forth across a small area of shallow water on the margin of the lake while her brood of six young, in a compact flock, swam out toward the lake's center. This incident took place while I stood on shore. On the same day, at another smaller lake, a female flew out from a thick clump of rushes, and, alighting beside my canoe, made the usual demonstration. A few minutes later a brood of eight young, about two weeks old, rushed out from the same section of cover and dispersed over the surface of the lake. After a few minutes the brood reformed and swam along the marsh edge while the female swam between it and my canoe.

The behavior of a female with brood when approached by a man on foot is altered to suit this different situation; she then attempts, by fluttering along the ground with one or both wings dragging, to draw attention away from the brood.

Several females with broods may combine under the stress of excitement caused by human intrusion, and together defend their young. One such instance involving three females and a group of 19 young has been recorded elsewhere (10) (Fig. 2). Another example is that of three females accompanying a band of 14 half-grown young on Pete Kitchen Lake, Cariboo Parklands, July 18, 1938. A third, illustrated by Fig. 3, concerns two combined broods rushing to shore cover on Mirage Lake, while the females perform defense actions on the water.

The defense tactics of the female green-winged teal when directed towards a man cannot conceivably be of any survival value, for in most instances the presence of a brood in the marsh growth would not have been detected had the female remained with it. It is conceivable, however, that had they resulted from the presence of a different type of predator, for example a coyote hunting along the edge of the marsh, the tactics would have definite survival value.

The earliest and latest dates for the first records of downy young are June 20, 1940, and Aug. 10, 1919, respectively.

The average number of young in 48 broods counted in July and 17 broods counted in August was the same, viz., 6.2. The high average survival may be attributed in part to the vigorous defense reactions of the females.

#### *Postbreeding Behavior, and the Eclipse Plumage, of Males*

It is usual to find several adult males associated on a common loafing place even during the early part of the laying period, and such places they may continue to occupy for the first week or so of incubation. By this time some males have begun to molt, and the bright colors of the nuptial dress is approaching an eclipse. Soon all males have retreated to the seclusion and comparative safety of a marsh habitat so necessary to survival during the flightless period of molt that is to follow. Thus in the Lakes District, Vanderhoof region, in the summer of 1945, all males had disappeared from open water by the first week in July. One instance of an adult male in full eclipse in company with a female and seven half-grown young was observed at Lily Pad Lake, July 21, 1939.

In the Cariboo Parklands males begin to assume eclipse plumage in late June and early July. There is much individual variation in the time of molt. Thus, at 149 Mile Lake, July 19, 1939, two males still were in full nuptial plumage—so far as could be determined by careful scrutiny with 8× binoculars, while at Lily Pad Lake two days later two other males were observed to have attained full eclipse. On July 13, 1943, all of four adult males, flushed together from a round-stem bulrush marsh at 103 Mile Lake, and nine males flushed singly from the marshes at Watson Lake on July 23, were in full eclipse. None has been observed during the flightless period that, presumably, occurs with most individuals from late July to early August.

The molt of the contour feathers from eclipse to nuptial plumage is a slow process, with flank feathers the last to be renewed. A specimen from Swan Lake, Okanagan, Oct. 14, 1939, retains eclipse feathers among the greater wing coverts, and, in the finely vermiculated nuptial plumage on the flanks, eclipse feathers are conspicuous. The molt of young males is continued over a still longer period. A specimen from Swan Lake, Sept. 28, 1936, another from Okanagan Landing, Oct. 15, 1920, show no adult feathers. One from the last locality, Dec. 12, 1930, retains a few juvenile flank feathers, and juvenile feathers predominate on the back.

#### Sex Ratio

A total of 4264 green-winged teal, with sex recorded, was banded at Coast Stations; of these 2225, or 52% were males, and 2039, or 48% were females. On 119 of the 255 banding days the number of males exceeded the number of females; on 32 days the proportion of the sexes was equal, and on 104 days the number of females exceeded the number of males.

The greatest daily sexual disproportion is indicated by the following figures: males in excess of females 34/11, 36/23, 66/40, 30/18, 167/75, 37/13, 24/8; females in excess of males 50/23, 49/38, 59/42, 23/7, 50/30, 63/24, 72/65. There is no regular seasonal change in the picture of general balance between the sexes. At Station 2 during March and April of 1933 more females than males were banded, viz., 325 and 296 respectively, but in 1934 and 1935, during the same two months, this was reversed, with 186 males and 108 females banded.

Field observations of spring and winter flocks, when differences in the appearance of the sexes make recognition certain, has provided no evidence of sexual segregation on migration, neither do they suggest any disproportion in numbers between the sexes as sometimes is apparent with other duck species; for example, the pintail.

#### Food and Feeding Habits

The food range of the green-winged teal is not extensive; seeds of aquatic plants, aquatic insects, molluscs, and crustaceans seem to be preferred in that order. Much food is obtained from the surface of ponds and shallow lakes.

In such places it is common to see these small ducks gliding here and there across the surface as minute objects are picked from the water, or pausing to submerge head and neck among the dense foliation of pond weeds or widgeon grass, where amphipods, insects, and seeds usually are plentiful. Foraging for similar foods in the rich vegetation of shoreward shallows, they tip up in the manner of all pond ducks, and so also they seek food of this sort along lake margins where wind-blown flotsam litters the shore. In shallow *Chara* meadows they seek out the oospores and avoid the branches that seem unattractive to them; apparently the leaf material of aquatic plants also seems unattractive. In winter, along the coast, flood ponds are visited in evening and morning following flights from the sea, and here they find weed seeds of many kinds.

Swarth (13) reports finding the eggs of humpback salmon, *Oncorhynchus gorbuscha*, in the gullets of green-winged teal collected on the Kispiox River, but the habit of feeding on salmon eggs has not been detected along the Pacific Coast.

The stomach contents of 55 adult green-winged teal collected in the Okanagan Valley, the Cariboo Parklands, and the Peace River Region of the interior, and 14 specimens from the mouth of the Fraser and from localities on Vancouver Island have been studied. The results in summary follow.

#### *Food of Downy Young*

The stomachs of two downy young, taken in June at Tupper Creek, Peace River region, contained insect material to the extent of 100% in one and 60% in the other, the food in largest bulk being the pupae of a midge (Ceratopogonidae); other insects represented were a midge larva, *Caoborus* sp., caddis larva, terrestrial coleopteran, and dragonfly nymph. Egg cases of *Cladocera* sp. were present in both stomachs and one contained a small amount of filamentous alga, *Zygnuma*.

#### *Food of Adults, Interior Region*

All the stomachs are from specimens collected in September. A well-filled stomach from "Disputed Lake", near Horse Lake, in the Cariboo Parklands, contained the following insects: several dragonfly nymphs (Anisoptera), six damselfly nymphs (Zygoptera), 20 caddis-fly larvae (Phryganeidae),  $70 \pm$  mayfly nymphs (Ephemerida), and 10 chironomid larvae. Other animals present were: 1 leech,  $100 \pm$  small gastropods (*Planorbis* sp.), and  $25 \pm$  minute pelecopods. The plant material eaten included a quantity of water moss (*Fontinalis* sp.), and a few seeds each of *Potamogeton* sp., *Eleocharis* sp., *Sparganium* sp., and *Carex* sp. A small amount of a blue-green alga also was in the stomach. A specimen from Horse Lake contained seeds of *Scirpus acutus*, *Eleocharis palustris*, *Polygonum hydropiper*, *Carex* sp., and fragments of dragonfly nymphs. One from 103 Mile Lake held vegetable material only, including seeds of *Scirpus acutus*, *Potamogeton pusillus*, and *Carex* sp. In another from Tatton Lake, chironomid larvae constituted 80% of the contents, the balance being fragments of corixids,  $100 \pm$  seeds of *Scirpus acutus*, 20 seeds

of *Potamogeton pusillus*, and one *Myriophyllum spicatum* seed. A few bryozoan statoblasts also were in the stomach. *Chara* oospores was the principal food eaten by three specimens collected at a meadow slough, near the north end of Okanagan Lake; in one, this item amounted to 100%, in the others, 70% and 60% of the total food. One had also eaten 38 seeds of *Scirpus acutus*, the other a small quantity of vegetable matter that was not identified.

The contents of 46 stomachs containing food collected at Swan Lake, Sept.—11, Oct.—26, Nov.—9, are summarized below.

**Crustaceans.** One stomach contained 8+ specimens of *Hyalella azteca*, constituting 20% of the contents; another 15% of *Gammarus limnaeus* debris; and traces of amphipods were noted in two others.

**Insects.** Aquatic insects were represented in 26 stomachs by amounts varying from less than 1%, to a maximum of 80%, of total contents. Corixidae were present in 13, *Chironomus* sp. larvae in one, Chironomidae larvae in four, and other insect groups as follows: Odonata—dragonfly nymphs 3, damselfly nymphs 2; Gyrinidae—larvae 3; *Dytiscus* sp.—larvae 3; terrestrial insects (adult Coleoptera) occurred twice and represented 40% of the total food in one, and 5% in another stomach. Insect debris in small amounts and not further identified was noted in seven specimens.

**Molluscs.** Minute *Physa* sp. and/or *Planorbis* sp. and mollusc debris occurred in nine stomachs, representing percentages of 75, 50, 40, 20, and minor items.

**Miscellaneous animals.** Leech egg cases,  $100 \pm$ , constituted 70% of the food in one stomach, and this was a minor item in two others; bryozoan statoblasts occurred in three, in one forming 24% of the food eaten.

**Chara** oospores. The oospores of *Chara* were present in 11 stomachs, and in six of them constituted 25 to 90% of the food present.

**Scirpus** seeds. The achenes of round-stem bulrush, *Scirpus acutus*, is the food item represented most often, and in the greatest volume. It occurred in 39 of the 46 stomachs examined, in 15 composing 90 to 100%, in 13 others 50 to 80%, and in the remainder from four to 36% of the total food in the stomach.

**Miscellaneous seeds.** Seeds of aquatic plants other than *Scirpus acutus* occurred less frequently and in smaller amounts; the species and times of occurrence are: *Carex* sp. 1, *Eleocharis palustris* 2, *Sparganium* sp. 2, *Rumex maritimus* 3, *Zannichellia palustris* 2, *Polygonum amphibium* 3, *P. convolvulus* 1, *Myriophyllum spicatum* 3, *Potamogeton pectinatus* 4, *P. pusillus* 2, *P. heterophyllum* 3.

**Miscellaneous vegetation.** In this category are: one occurrence of winter buds of *Potamogeton pectinatus*; two of the root bulbils of *Chara*, in one instance composing 100% of the food in a partly filled stomach; one of nostoc; and one of an unidentified alga.

### Food of Adults, Coast Region

The stomachs of 16 green-winged teal from the Coast Region have been examined; localities represented, numbers of specimens, and months in which they were taken are: Fraser River mouth (Ione Island, Sea Island, Lulu Island), Nov.—1, Dec.—2, Jan.—1; Boundary Bay, Oct.—4; Colquitz, Jan.—1; Cowichan Flats, Nov.—1, Jan.—2; Departure Bay, Jan.—1; Nanaimo Meadows, Jan.—1; Crofton Flats, Nov.—1. The last five localities are on Vancouver Island.

**Crustaceans.** There were three occurrences of marine amphipods from Sea Island, Boundary Bay, and Nanaimo Meadows, in one constituting 40, in another 25% of the stomach contents.

**Molluscs.** Small marine gastropods represented 50% of the contents of a specimen from Departure Bay.

**Insects.** Adult diptera were present in two from Boundary Bay, in volume percentage of 40 and 50 respectively. Both of these ducks and one from Cowichan Flats had eaten terrestrial coleopterans. In another were two larvae of an aquatic beetle. Chironomid larvae was the largest food item in a specimen from Nanaimo Meadows.

**Miscellaneous animals.** Here are placed one occurrence of polychaete jaws present in a stomach from Boundary Bay; and an occurrence of unidentified fish eggs that composed 80% of the contents in a Cowichan Bay specimen.

***Scirpus* seed.** The seeds of a three-square bulrush, *Scirpus americanus*, was the chief food in three specimens from the Fraser River mouth and represented 40% of the food in another. Elsewhere it was recorded only from the Cowichan Flats and as a minor percentage.

**Miscellaneous seeds.** Thirteen specimens contained seeds, other than *Scirpus*, and composed 50% of the total volume in a specimen from Departure Bay. *Carex* species occurred five times in varying amounts. *Eleocharis palustris* occurred four times, volume percentage up to 25; *Polygonum amphibium* occurred twice, *P. lapathifolium* and an unidentified polygonum occurred once each. Seeds of other plants, which occurred in small amounts, are: *Sparganium* sp., *Bromus* sp., *Atriplex* sp., *Distichlis patula*, and *Salicornia ambigua*.

### Food Summary

One of two downy young from the Peace River District had eaten insects exclusively, the other to the extent of 60% of the stomach contents. The chief constituent in each was a midge pupa. In 53 stomachs of adults from the interior vegetable matter constituted 66% and animal matter 34% of the total food eaten. As indicated by frequency of occurrence preference was shown for various foods in this order: seeds of aquatic plants, including 45 occurrences of *Scirpus acutus*; insects including Odonata nymphs, chironomid adults and larvae, corixids, and coleopteran adults and larvae; *Chara*

TABLE VIII

FREQUENCY OCCURRENCE OF IDENTIFIED FOOD ITEMS IN 69 GREEN-WINGED TEAL STOMACHS

Waterflea, <i>Cladocera</i>	Egg cases	1
Amphipod, unidentified marine form		3
Amphipod, unidentified freshwater form		1
Amphipod, <i>Hyalella azteca</i>		1
Amphipod, <i>Gammarus limnaeus</i>		1
Leech (Hirudinea)	Egg cases	2
Leech (Hirudinea)	Adult	1
Damselflies, <i>Enallagma</i> spp.	Nymph	3
Dragonflies (Odonata)	Nymph	4
Water boatman (Corixidae)	Adult	14
Caddis flies (Trichoptera)	Larva	2
Beetle, terrestrial	Adult	8
Beetle (Gyrinidae)	Adult	1
Beetle (Dytiscidae)	Larva	2
Beetle, aquatic	Larva	5
Beetle, <i>Halophilus</i> sp.	Adult	2
Beetle, <i>Halophilus</i> sp.	Larva	1
Midge (Chironomidae)	Adult	2
Midge (Chironomidae)	Larva	3
Midge (Ceratopogonidae)	Pupa	2
Midge, <i>Caobornis</i> sp.	Larva	1
Fly (Diptera)	Adult	2
Mussel, <i>Pisidium</i> sp.		1
Snail, unidentified freshwater form		6
Snail, unidentified marine form		1
Snail, <i>Planorbis</i> sp.		4
Snail, <i>Physa</i> sp.		1
Marine worm (Polychaeta)		1
Bryozoa	Statoblasts	4
Muskgrass, <i>Chara</i> sp.	Oospores	14
Muskgrass, <i>Chara</i> sp.	Bulbils	2
Algae, unidentified freshwater forms		3
Filamentous alga, <i>Zygnuma</i>		1
Water moss, <i>Fontinalis</i> sp.		1
Bur-reed, <i>Sparganium</i> sp.	Seeds	3
Pondweeds, <i>Potamogeton</i> sp.	Seeds	3
<i>Potamogeton heterophyllum</i>	Seeds	3
<i>Potamogeton pusillus</i>	Seeds	4
<i>Potamogeton pectinatus</i>	Seeds	4
<i>Potamogeton pectinatus</i>	Winter buds	1
Horned pondweed, <i>Zannichellia palustris</i>	Seeds	2
Salt grass, <i>Distichlis patula</i>	Seeds	2
Brome grass, <i>Bromus</i> sp.	Seeds	2
Sedge, <i>Carex</i> sp.	Seeds	11
Bulrush, <i>Scirpus acutus</i>	Seeds	45
Bulrush, <i>Scirpus americanus</i>	Seeds	3
Spike rush, <i>Eleocharis</i> sp.	Seeds	2
<i>Eleocharis palustris</i>	Seeds	6
Dock, <i>Rumex maritimus</i>	Seeds	4
Bindweed, <i>Polygonum Convolvulus</i>	Seeds	1
Smartweed, <i>Polygonum amphibium</i>	Seeds	6
<i>Polygonum lapathifolium</i>	Seeds	1
<i>Polygonum Hydropiper</i>	Seeds	1
Glasswort, <i>Salicornia ambigua</i>	Seeds	1
Orach, <i>Atriplex</i> sp.	Seeds	3
Water milfoil, <i>Myriophyllum spicatum</i>	Seeds	4

oospores, molluscs, and crustaceans. In 16 stomachs from the coast, vegetable matter constituted 67% and animal matter 33% of the total contents. Seeds of aquatic and shore plants were first in importance followed by insects, crustaceans, and molluscs in that order.

TABLE IX  
FOOD OF 69 ADULT GREEN-WINGED TEAL, PERCENTAGE OF TOTAL VOLUME

Localities and number of specimens	Crustaceans	Insects	Molluscs	Misc. animals	<i>Chara</i> oospores	<i>Scirpus</i> seeds	Misc. seeds	Misc. vegetation
Tatton Lake	1		81.00		1.00		15.00	3.00
103 Mile Lake	1						1.00	39.00
Horse Lake	1		30.00				30.00	40.00
"Disputed" Lake	1		55.00	15.00	5.00			15.00
Pond, Okanagan	3					76.66	13.34	10.00
Swan Lake	46	1.09	11.72	4.65	2.11	7.17	50.66	12.59
Mouth Fraser River	4	27.50					51.50	11.00
Boundary Bay	4	6.25	63.00			10.00		2.50
Colquitz, V.I.	1							100.00
Crofton, V.I.	1							100.00
Cowichan Flats, V.I.	3				26.66		3.34	70.00
Nanaimo Meadows, V.I.	2	2.50	45.00					50.00
Departure Bay, V.I.	1		50.00					50.00

### Economic Status

Unlike certain other duck species the green-winged teal has exhibited no tendency to feed on agricultural crops, neither do its habits conflict otherwise with human interests. In this respect then its economic status is neutral. The value of the waterfowl resource in terms of national economy was noted in earlier papers of this series and it need only be mentioned here that the green-winged teal constitutes an important element in this resource. It stands high on the list of table birds and is a game duck of distinction—the more discerning appreciating the quality of speed in flight that tests the hunter's skill.

### Acknowledgments

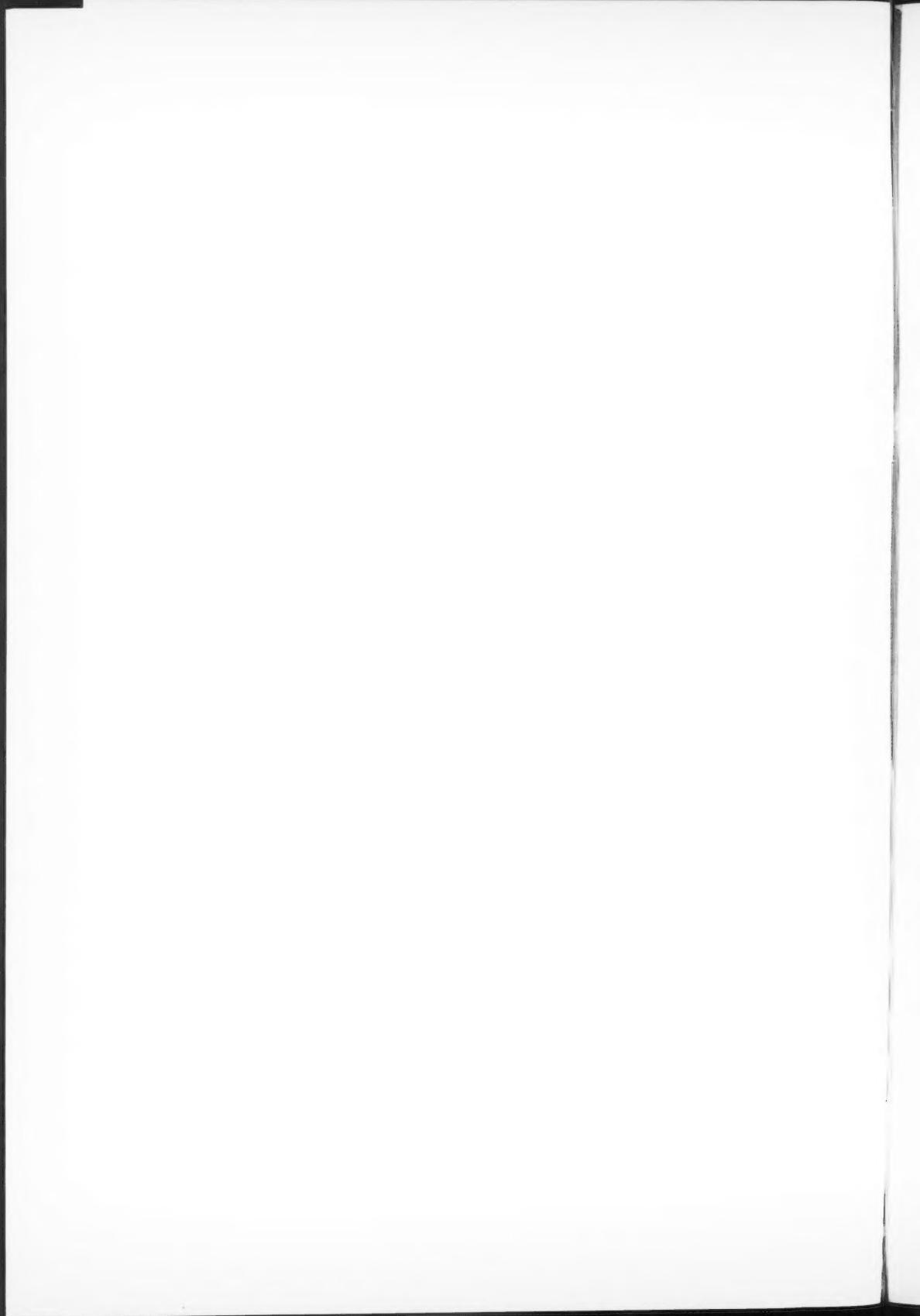
During the course of this study laboratory facilities were provided by Dr. R. E. Foerster, Director, Pacific Biological Station, and by Dr. G. Clifford Carl, Director, British Columbia Provincial Museum. Dr. I. McT. Cowan, Mr. Kenneth Racey, and Mr. Robert Luscher provided some of the green-winged teal stomachs reported on, and from the British Columbia Game Commission many of the banding data were obtained. In acknowledging this helpful co-operation I wish to extend my grateful thanks.

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